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THE WHAT'S NEW MAGAZINE

AUGUST 1994

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VOLUME 245

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NUMBER 2

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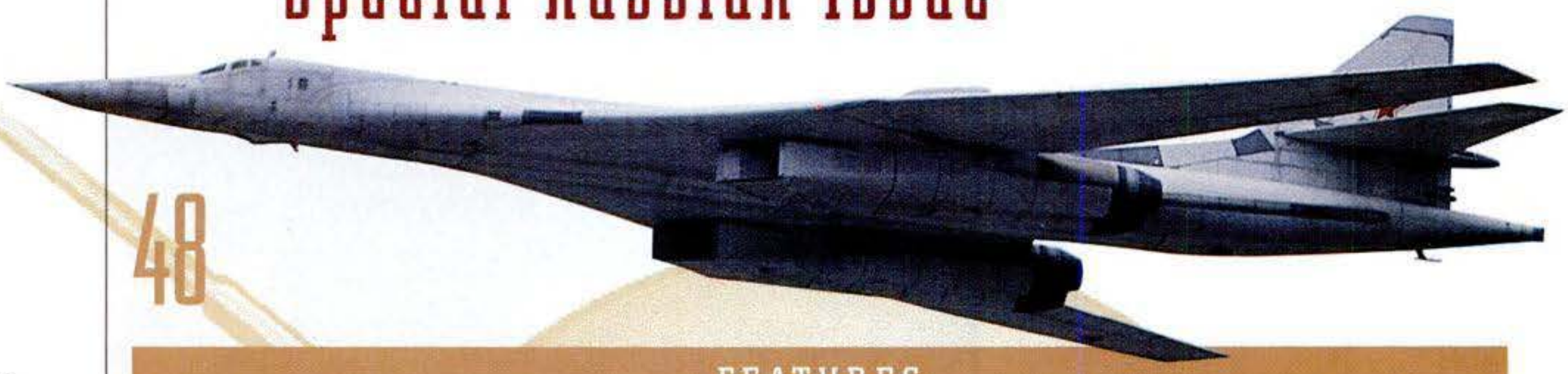
COVER BY TOM WHITE

Special Russian Issue



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Nuclear weapons, waste, and poorly designed reactors present a threat to the entire world.

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The father of Russian computing has formed a symbiotic relationship with Silicon Valley.

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The Soviet Union is dead, but the world's most successful space program lives on.

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This One

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3

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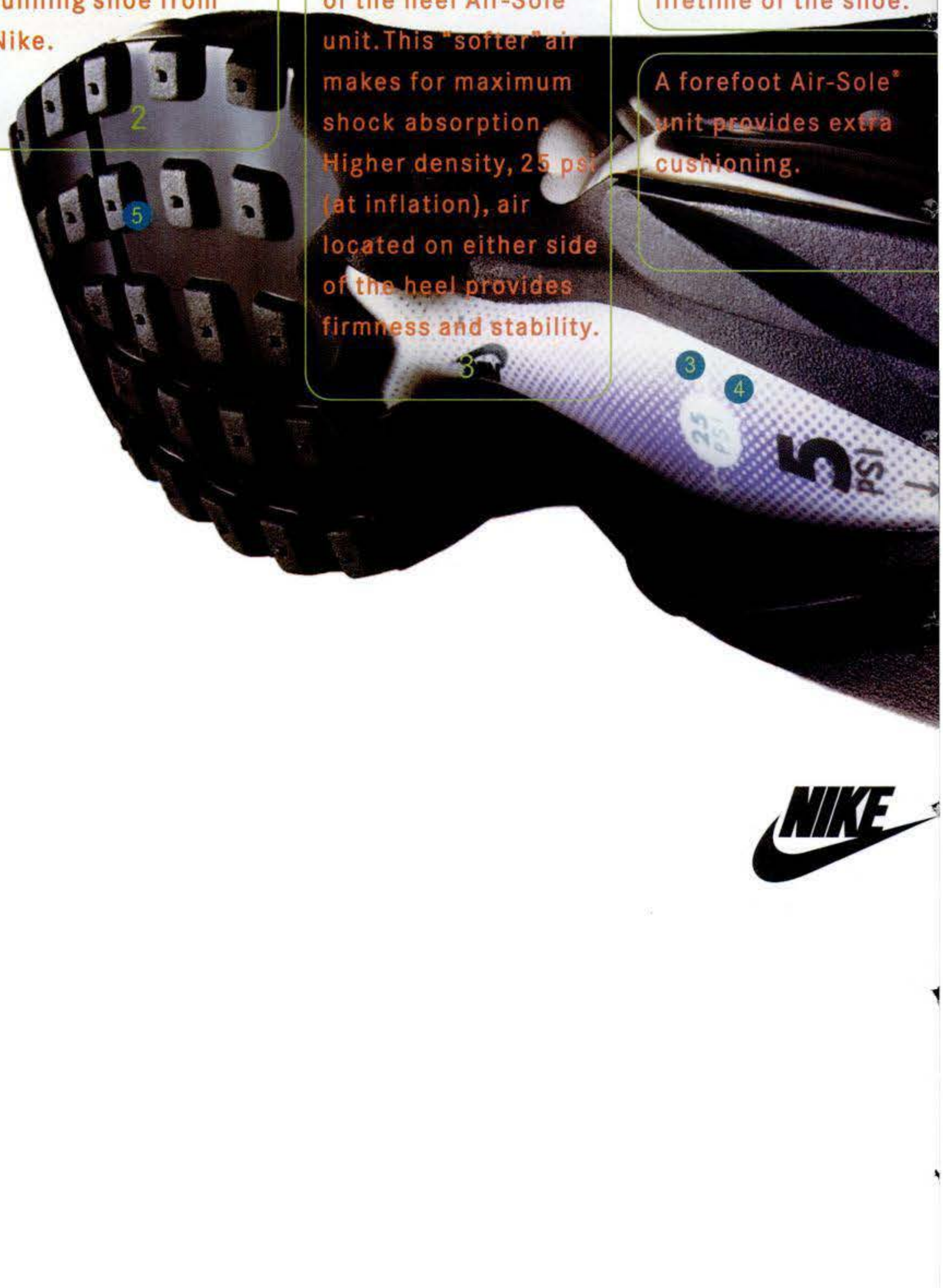

NIKE

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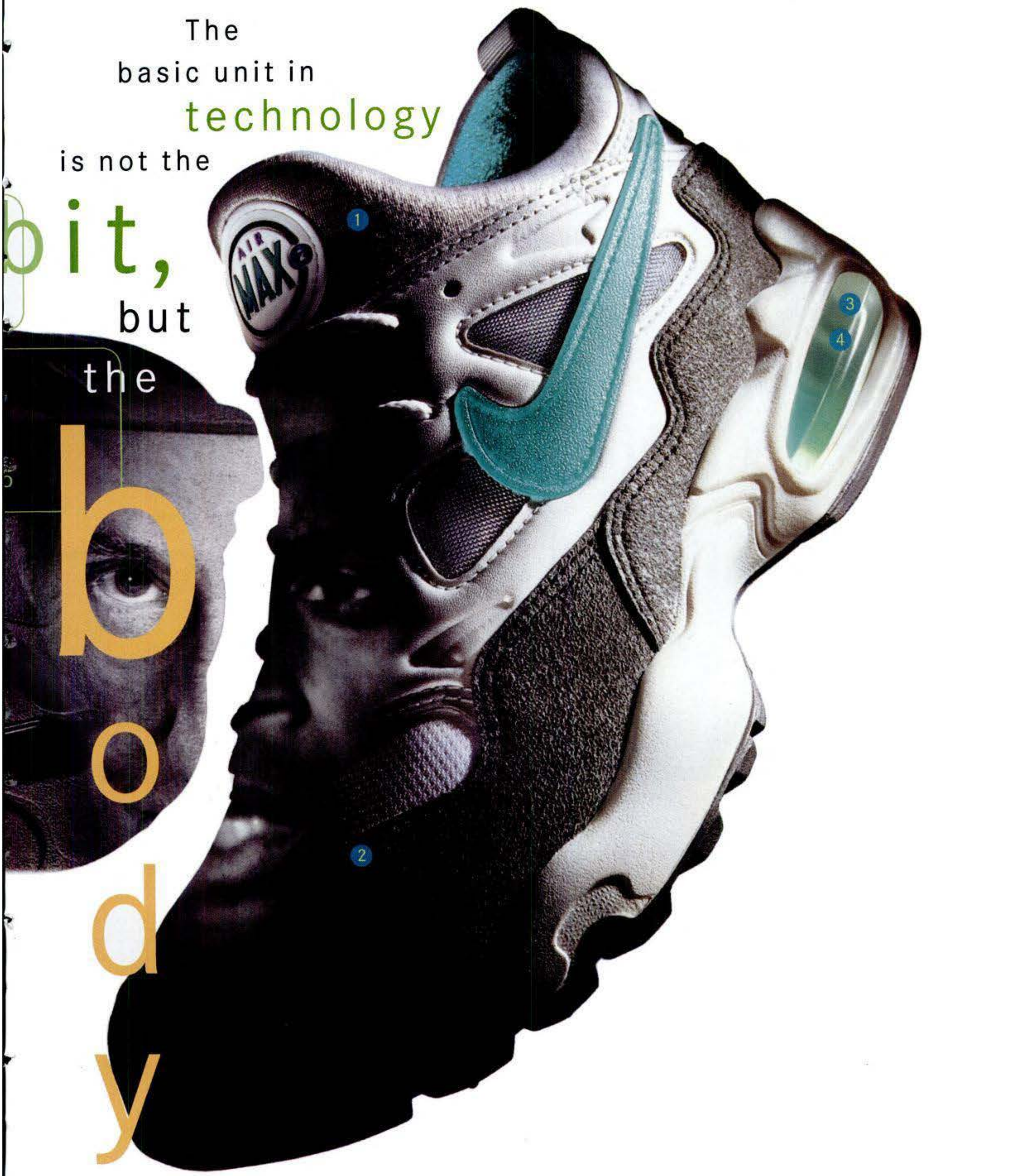
The basic unit in technology is not the bit, but the body



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EDITOR'S NOTE

Is There Life After Death For Russian Science?

It seemed on a par with England selling the crown jewels or the United States holding a fire sale at the National Archives. A total of $6.8 million worth of spacecraft, medals, documents, cosmonauts' gear—226 items in all from the former Soviet Union's once-glorious space program—sold on the block. The auction of space mementos was a harsh reminder of how far science and technology in the former Soviet Union have plummeted.

Right now, a revolution is unfolding in Russia that is marked by economic collapse, political instability, and social chaos. Russia is broke, and there is little money for science.

The decline of Russian science and technology is a cataclysmic event in its own right, threatening not only Russia's well-being but our own as well. Its past, signal contributions range from the invention of the periodic table of elements to the pace-setting strides in space that literally embarrassed the United States into launching a competing space program.

As wrenching as conditions are for Russian science, America and the rest of the world have a stake in its fate. In whose employ will some of the world's best nuclear scientists toil? Will there be future Chernobyl-like disasters? Will an economically desperate government ruthlessly exploit vast virgin lands to the environmental peril of all the world's inhabitants?

These and many other questions prompted us to deal with the state of Russian science and technology in this special issue. We have sought to provide a chronicle of past achievements, a status report on current conditions, and where possible, a forecast of future prospects. For this ambitious project, we called upon some special help in the form of experts and insiders. Most notable is Roald Sagdeev, the youngest person ever elected to the Soviet Academy of Sciences and former head of the Russian Space Institute. Sagdeev, who is now a distinguished professor of physics at the University of Maryland, offers a behind-the-Iron-Curtain account of how the Soviets developed their first atomic bomb, as well as his perspective on a KGB officer's controversial allegations of espionage by our own Manhattan Project scientists.

Russian-trained journalist Leonid Zagalsky tells us what life is like today for the average family, whose income is $30 per month. Fred Pearce of Britain's *New Scientist* magazine reports on his first-hand visit to the vast Siberian countryside, now under environmental siege.

Other contributors include William Burrows, director of New York University's Science and Environmental Reporting Program, who writes of the chaos on the Russian nuclear front, and aviation expert Bill Sweetman, who gained unprecedented access to formerly secret and off-limits Russian facilities.

Sweetman (left) and Fisher in Moscow.

This issue was directed by our own award-winning Science and Technology Editor Arthur Fisher, who made his fourth trip to what was once the Soviet Union last April. Fisher was stunned by the anything-goes bedlam in Moscow today but reassured by the dogged optimism expressed by many of the Russian scientists and officials he spoke with.

"The Russians firmly believe," Fisher says, "that international cooperation will save their science."

Indeed, there may be life after death for Russian science and technology. It simply won't be soon and it won't be easy.

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READERS TALK BACK

Where Does It All Go?

In "Emerging Technologies for the Supercar" [June], the diagram showing where a car's fuel energy goes contains some funny numbers. As an engineer, I believe that energy losses in the engine amount to about 80 percent of fuel input, not 62.4 percent, as the diagram shows. Also, the diagram seems to account for all types of losses, except for what happens to the 13.6 percent of fuel energy after it is used to drive the wheels.

Francis W. Jackson
Hatboro, Pa.

You're right about the numbers: Our diagram underestimates losses in a typical gasoline engine. According to information from Ford, in an urban driving cycle (stop-and-go), 81.8 percent of the potential heat of combustion is lost by the time it is turned into mechanical energy at the crankshaft. Driveline losses take an additional 5.6 percent, leaving 12.6 percent at the wheels. Of this 12.6 percent, aerodynamic drag and rolling resistance eat up 6.8 percent, leaving 5.8 percent to accelerate the vehicle—energy that ultimately is dissipated by the heat of braking. The ratios differ at a constant highway speed, by the way; aerodynamic drag becomes more important and braking loss, less so.—Dan McCosh

Bits About Boeing

You state that the 777 is being built at a Boeing factory, but fail to mention that the fuselage is made in Japan ["The Newest Way To Fly," June].

Edward Fregin
Simi, Calif.

Planes use domestic as well as foreign parts. For the 777, Boeing has 545 suppliers, 58 of them foreign. The Japanese aerospace industry is the largest foreign contributor, supplying 20 percent of the airframe—but not the entire fuselage. For the 777, Boeing estimates that seven Boeing jobs were created for every one overseas.—Dawn Stover

I've flown many of Boeing's fine airplanes, from the P-26 to the B-52. The computer-designed fly-by-wire 777 sounds like another winner. The customer research that led to such innovations as pop-out light bulbs and non-slam toilet seats is impressive. But who told Boeing that passengers enjoy flying nine abreast?

James V. Edmundson
Lt. Gen., U.S. Air Force (Ret.)
Longboat Key, Fla.

Super I-Way Guide

Your article on the "Information Superhighway" [May] serves as an excellent guide for nonprofit professionals who are not technology oriented.

Jim Yu
United Way of America
Alexandria, Va.

Hauling Earth

With its creative mixture of fictitious narrative and satirical reporting, "Greetings from the Chunnel" [May] was a great break from the usual article. However, it was missing details on the excavation. How was so much earth moved from the three tunnels?

Lyle T. Jackson
Grants Pass, Ore.

Eleven boring machines—some longer than two football fields and equipped with a grinding plate topped by 236 tungsten-carbide gouging bits—moved an estimated 245 million cubic feet of dirt, mud, and chalk marl. Contractor Transmanche-Link calculates that the task required more than 70,000 man-years from United Kingdom workers alone. For a full account of this process, see our story, "Journey Down the World's Longest Underwater Tunnel" [June '90].—Judith Anne Gunther

Corrections: The address of Best American Duffel, maker of the B.A.D. bag in "What's New" [June], is 2601 Elliott Ave., Suite 4317, Seattle, WA 98121.

In "The Digital Diamond" ["Computers and Software Newsfront," June], PlayBall offers advice from former big-leaguer Alan Bannister. ESPN Baseball uses former Miami coach Ron Fraser.

Webasto Sunroof is in Rochester Hills, Mich. ["What's New," June].

In "The Cool Stuff" ["Automotive Newsfront," June], the path traveled by air-conditioning refrigerant was incorrectly described. Actually, hot refrigerant leaves the condenser, then passes through an accumulator/heat exchanger before heading to the evaporator. Now cooler, the refrigerant then enters the evaporator.

Address your letters to Readers Talk Back, POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016; fax them to 212-481-8062; or send electronic mail to our CompuServe account number, 75140,1732. The letters may be edited for space and clarity. Due to the volume of mail, we regret that we cannot answer unpublished letters.

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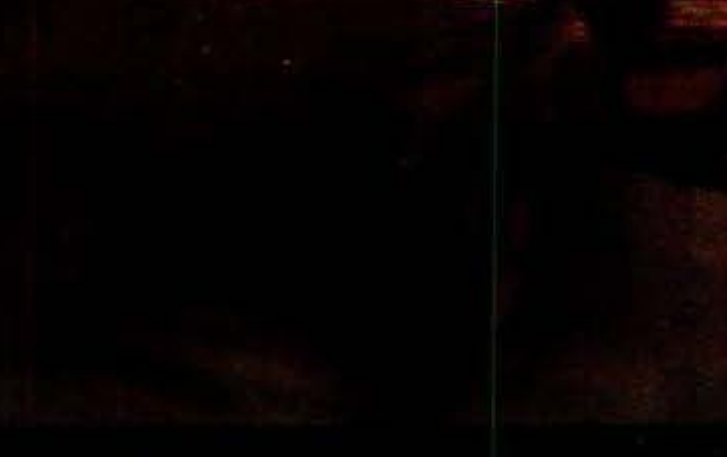

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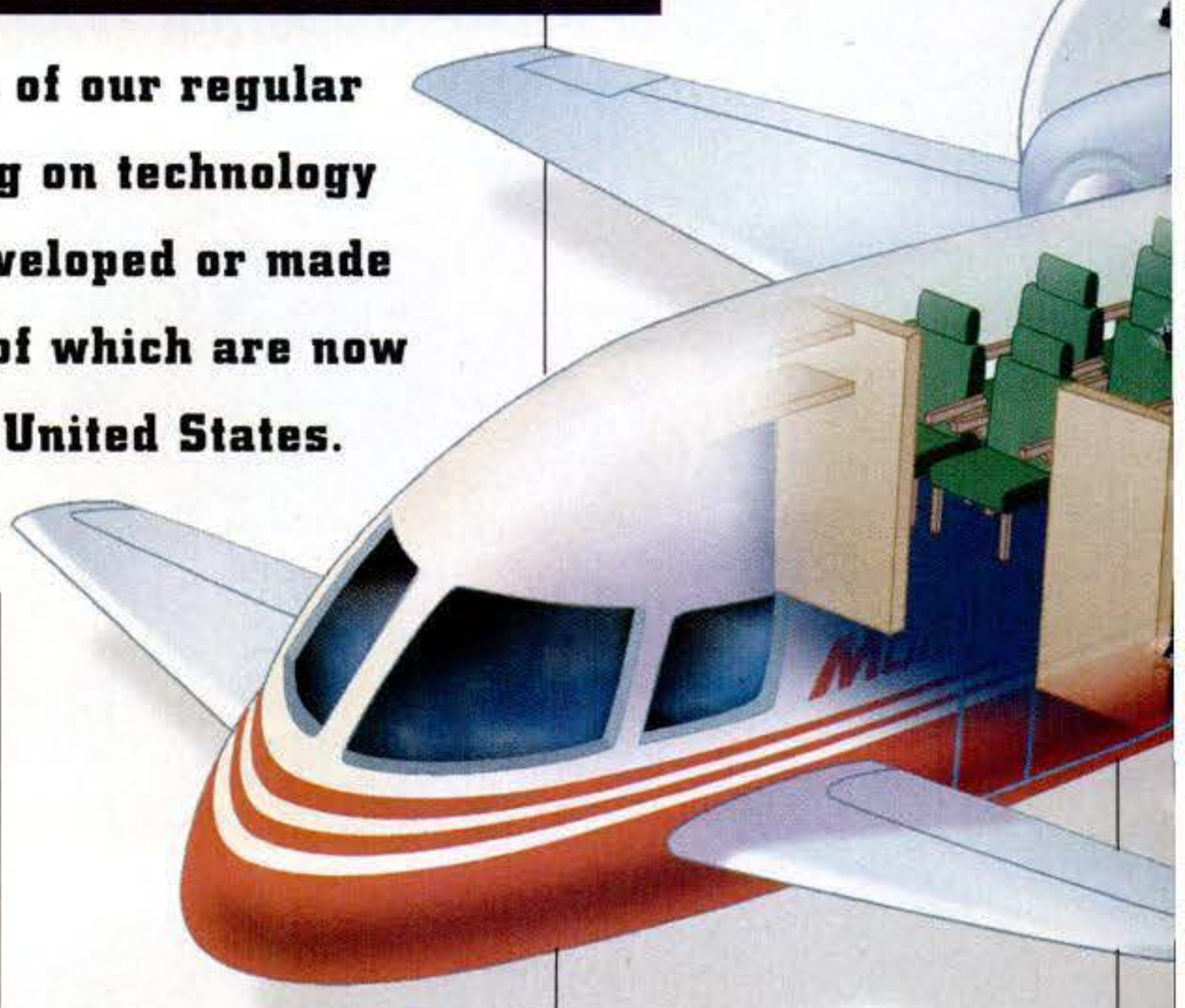
What's New

EDITED BY BOB SILLERY AND SUZANNE KANTRA

A special edition of our regular feature, focusing on technology and products developed or made in Russia, some of which are now available in the United States.

Night Goggles

The night lenses of choice for users who need both hands free, these goggles give the wearer stereoscopic vision at distances as great as 400 feet in very low light conditions. Price: $1,020 to $1,200. Interlink Group, 70 E. 55th St., New York NY 10022.

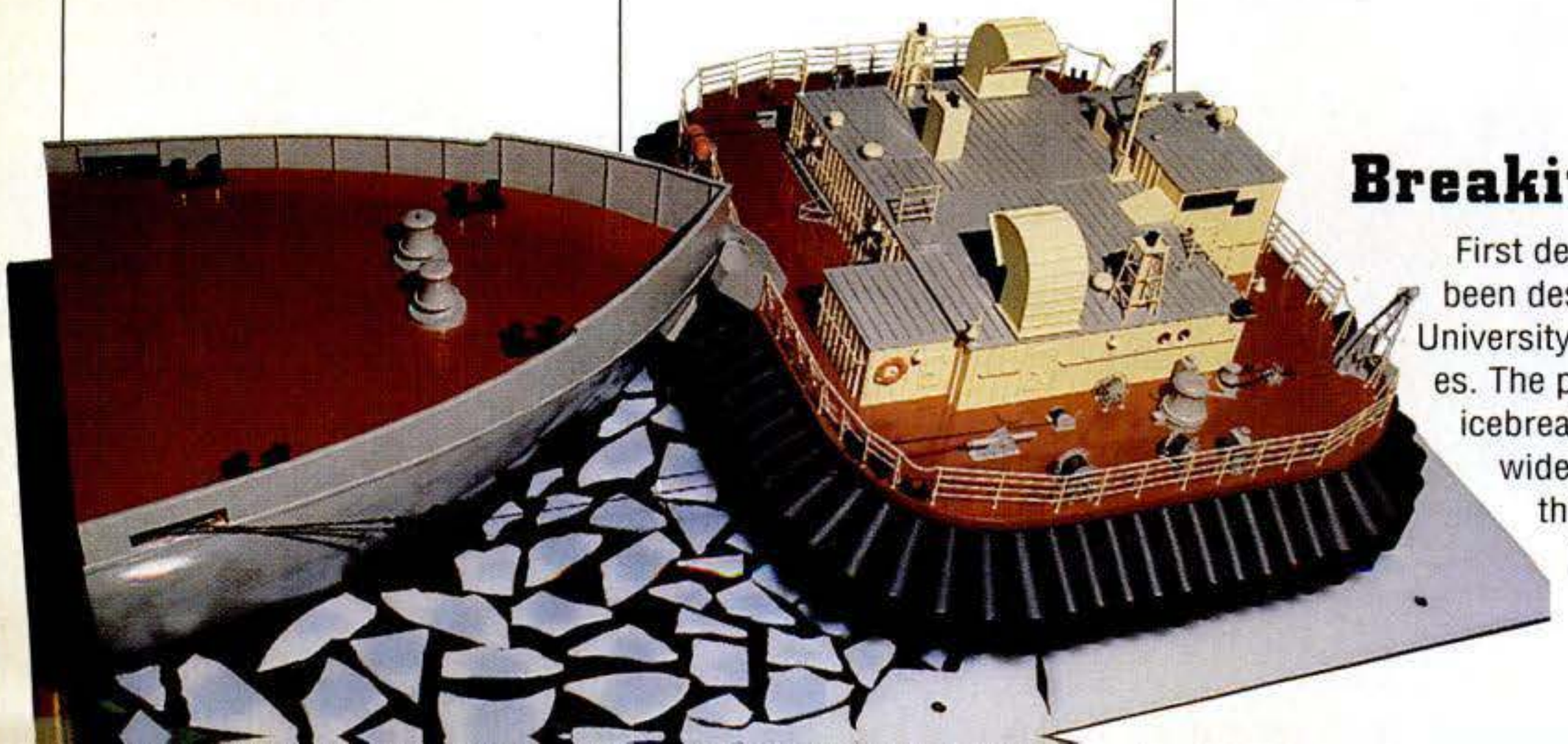


Executive Sedan

Volga engineers packed state-of-the-art technology into their new 3105 sedan aimed at Russia's emerging executive class. The powertrain is a 3.4-liter 170-hp fuel-injection V8, five-speed manual transmission, and full-time four-wheel drive. Rugged construction is reflected in the car's two-ton curb weight, all the better to withstand Russia's unpaved roads.

Test Your Mettle

It's a software invasion. A team of Russian designers created the Russian 6 Pak of computer games to challenge your mind and reflexes. Price: $30 (DOS), $40 (Windows). Interplay Productions, 17922 Fitch Ave., Irvine CA 92714.



Breaking The Ice

First developed for military use, this icebreaker has been designed by Nizhny Novgorod State Technical University to blast deeply frozen waters with air pulses. The platform can be coupled with a tug or other icebreaking vessel and can cut a swath 20 meters wide in one-meter-thick ice. Ventilators barrage the frozen obstruction with air, as the platform rides up on the ice. The vessel is controlled remotely.

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Commuter Liner

Russian defense contractors have conceived a flock of small new civil transport aircraft, such as the proposed Molniya-100, which features twin turboprop pusher engines and pitch control via nose-mounted canard fins.

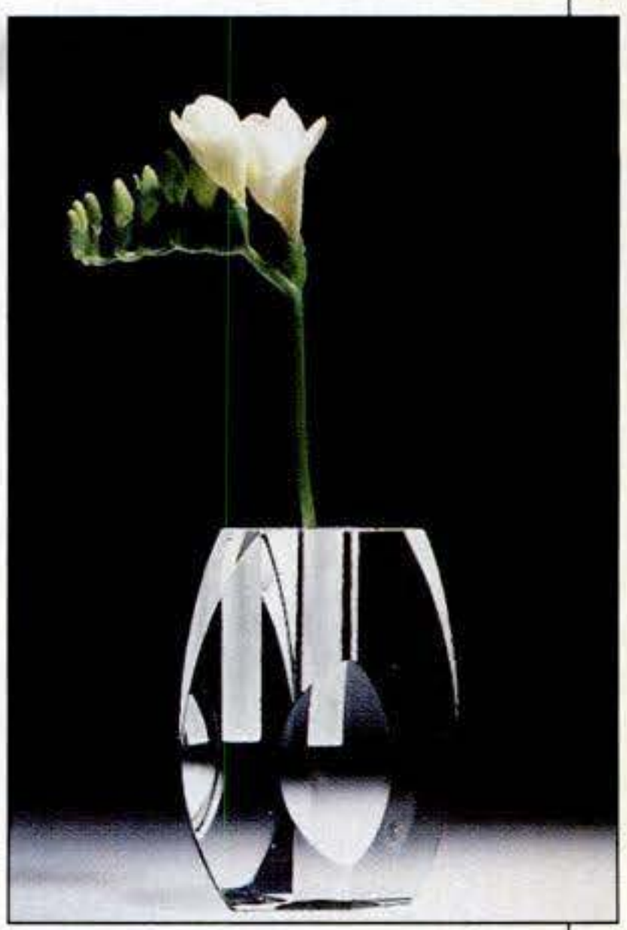
Spy Camera

"Intended for a particular circle of users," says the owner's manual for the Zenit MF-1, a favorite of the KGB. The three-inch-wide minicamera uses 35mm film cut down—in the dark—to 21mm width with a supplied trimming gadget. The focus of its 28mm f/2.8 lens is fixed at 15 feet. Price: $1,999. Moonlight Products, 5965 Pacific Center Blvd., Ste. 711, San Diego CA 92121.

ROB SCHUSTER

Countdown To Doom

If you're facing a deadline you can't bear to think about, perhaps a "Soviet doomsday clock" ticking away on the corner of your desk will remind you of the dire consequences—and then some. Described as an "actual launch clock for Soviet nuclear weapons," the clock is engineered to run for 500 years, according to the distributor. Price: $799. Clocks from MiG-29s, *Soyuz* spacecraft, tanks, and submarines are also available. Sunset Cliffs Merchandising Corp., Box 7518, San Diego CA 92167.



Recycled Eye-In-The-Sky

Soviet artifacts are undergoing some astonishing transformations. Who'd suspect this flower vase's secret past as a defective lens intended for a spy satellite? During the Cold War, these lenses were manufacturing casualties, but now artisans are overhauling them for a considerably less-sinister purpose. Price: $100. Sunset Cliffs Merchandising Corp., Box 7518, San Diego CA 92167.

Military Night Vision

Used by the Russian army, the MPN 60K night vision scope amplifies light 60,000 times and can spot objects 1,000 feet away in near-darkness. An image-intensifying device incorporates a fiber-optic connection that channels a bright image to the luminous-green phosphor viewing screen in the eyepiece. An optional infrared illuminator permits surveillance in total darkness. Price: $1,199. Moonlight Products, 5965 Pacific Center Blvd., Ste. 711, San Diego CA 92121.

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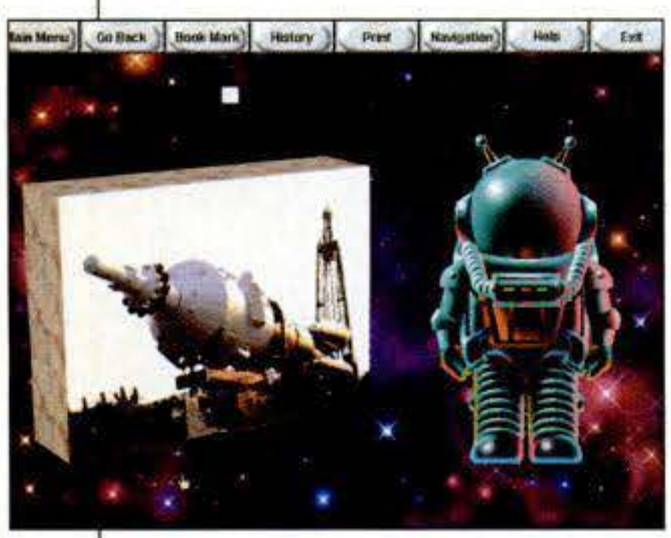
What's New

Saucer In The Sky

This "flying saucer," filled with a proprietary nonflammable gas, handles wind and cold better than regular blimps, says the Moscow Aviation Institute. The 130-foot-diameter Thermoplane could be used for lifting or as a flying billboard, hotel, or hospital. North American representative: Step One Technology, Inc., Marietta, Ga.

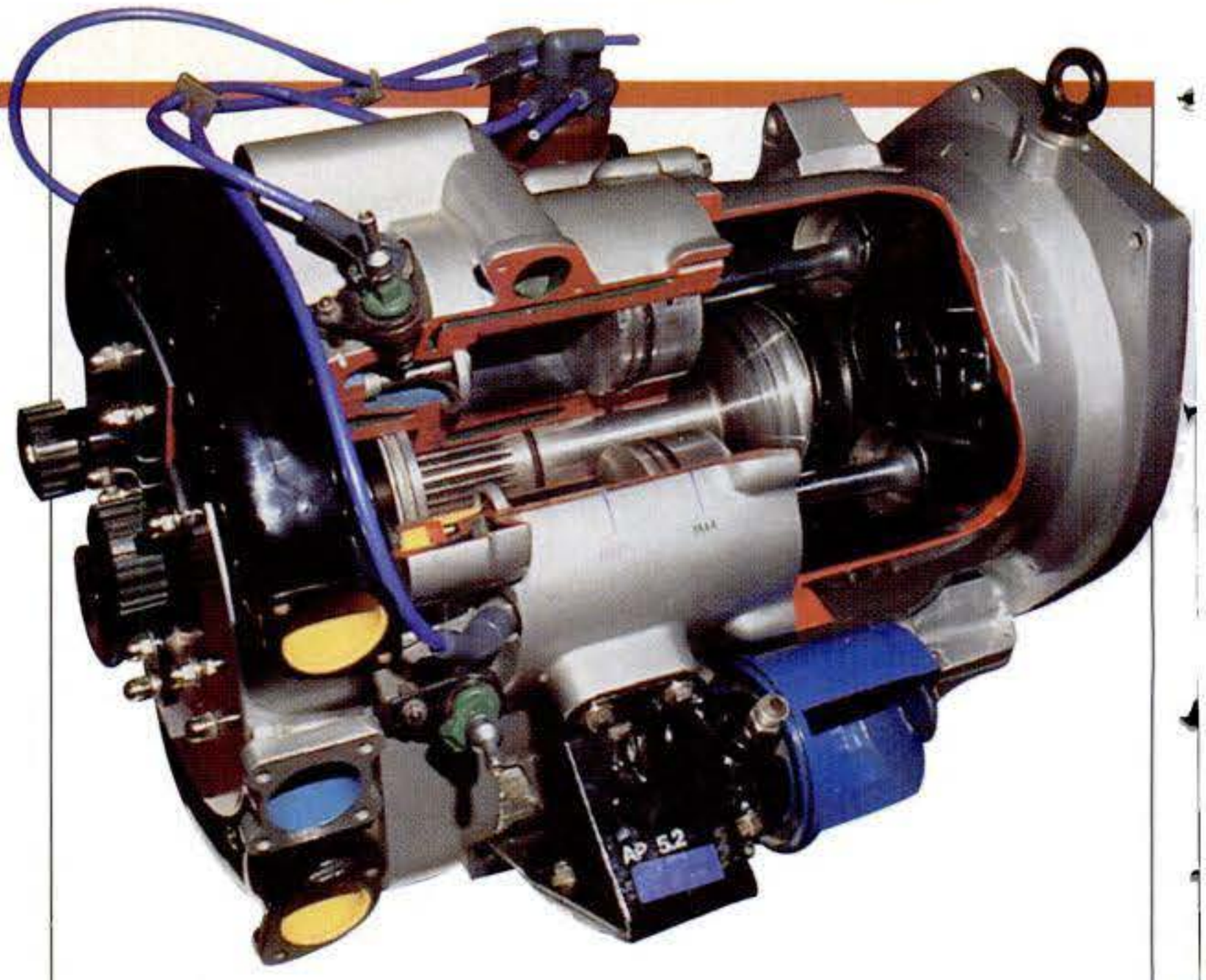


For Sputnik Fans

Once-secret documents dating back to the first Soviet space launches make up part of the presentation of The Soviet Space Program CD-ROM. It includes photos, video, narration, and reference materials linked by hypertext. For Macintosh and Windows systems. Price: $80. Published in a joint venture between CompactBooks of Moscow and Shoestring Multimedia, 444 DeHaro St., San Francisco CA 94414.

The KGB Was Here

The Soviet Union's notorious KGB used such glasses to facilitate spying. Now the "spy who came in from the cold" look can be yours. The 1 1/4-inch-long monocular makes things look two-and-a-half times closer and comes with a clever finger loop to steady the lens. The mini binoculars also magnify the view two-and-a-half times. Price: $15 (monocular), $20 (binoculars). U.S. Cavalry, Dept. P.O., 2855 Centennial Ave., Radcliff KY 40160.



Radial Concept

Researchers at the Russian Central Automotive Engine Scientific Research Institute in Moscow are working on a variable-displacement piston engine, potentially a fuel-efficient, lightweight design suitable for both autos and aircraft. The pistons are arranged radially, and a swash plate converts reciprocating into rotary motion—tilting the plate varies the piston stroke. Prototypes have produced 120 hp at 5,000 rpm. The configuration is similar to some air-conditioning compressors on U.S. cars.

The Elfmobile

If you thought elves resided only in Ireland, you're wrong. Made by AutoVAZ (16 Belorusskaya St., Togliatti 445633, Russia), the Elf (shown) is a variant of the Gnome minicar, with taller ground clearance and a removable top. The Gnome rolls on a 72-inch wheelbase, sports a 750-cc two-cylinder engine driving the front wheels, and makes it to 50 mph in a leisurely 16 seconds.

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What's New

Jet Trainer

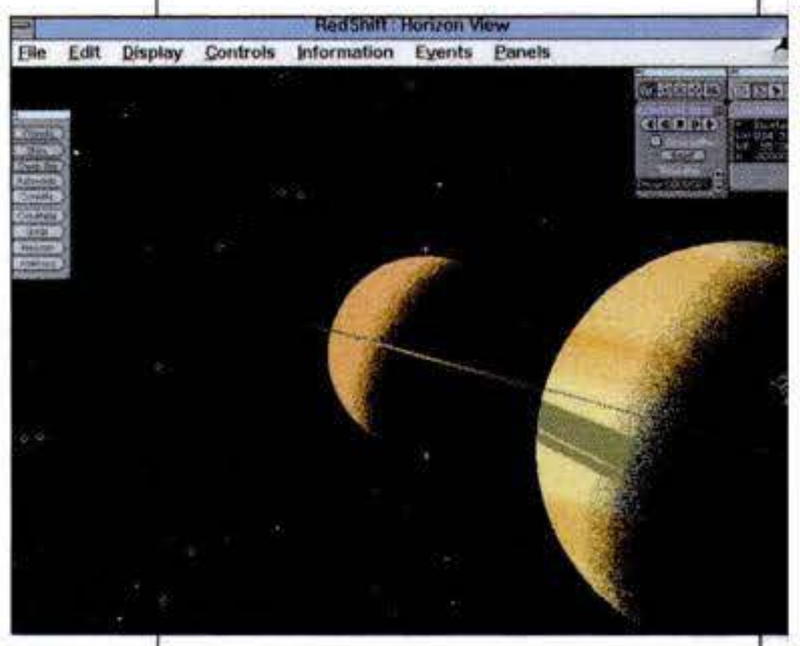
When the Cold War unwound, the aircraft design groups Yakovlev (Yak) and Mikoyan Gurevich (MiG) were developing new fighter-pilot training aircraft for the Soviet Air Force. The Yak-130 twinjet, now being built with the Italian company Aermacchi, uses reprogrammable computerized flight controls that can simulate the feel of various fighters. Its first flight is expected to be late this year.

Sporty Lada

Automaker Lada is beginning to export its wares to Great Britain, where the success of the Samara 1.5GL Flyte has encouraged it to try again. The Samara Springer is a sporty version of the Flyte car with a 1.3-liter engine. The Brits modify the raw import by adding a color-coordinated body-styling package, bumpers, sport wheels, a spoiler, and driving lights. In Britain, where car prices are high, the Russian wheels go for only $9,000.

Desktop Planetarium

Developers of RedShift Multimedia Astronomy CD-ROM used data from the Russian space program to develop a 3D voyage through space and time (4,000 B.C. to 10,000 A.D.). You can view photos and videos of 200,000 stars and 40,000 deep sky objects on Windows or Macintosh systems. Price: $99. Developed by Maris Multimedia near Moscow. Distributed by Maxis, 2 Theatre Square, Orinda CA 94563.



Sight-Seeing Sub

Unlike the submarine in *The Hunt for Red October*, the Sadko is meant for pleasure only. It can take up to 40 passengers on a one-hour sea tour at a depth of about 50 meters. Life support lasts for up to 72 hours. The 29-meter-long craft cruises at a speed of three knots. Central Design Bureau for Marine Engineering, 191126, St. Petersburg, ul.Marata, 90, Russia.

MARIO FERRO

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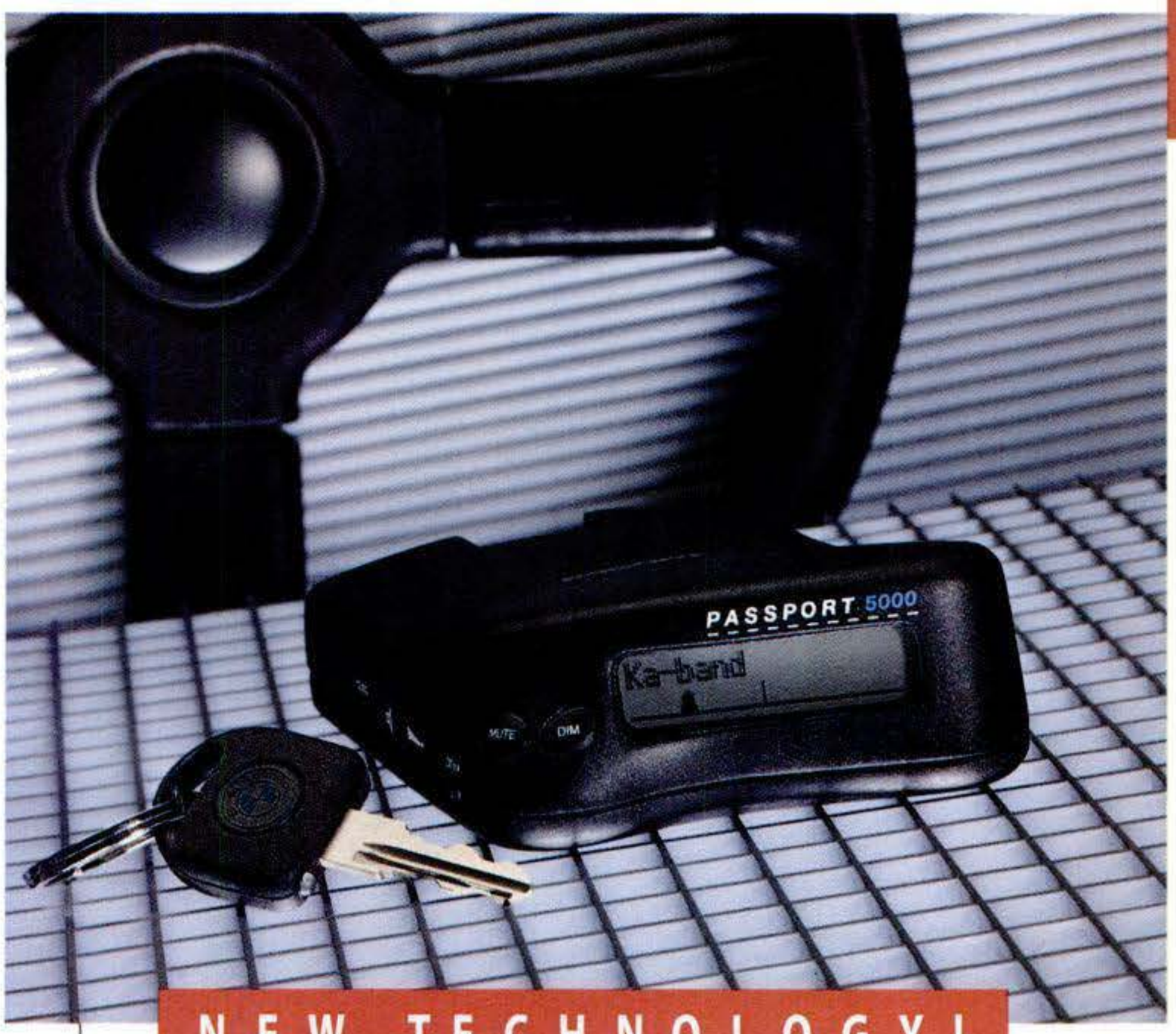

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This special Newsfronts edition highlights advances in science, computers, electronics, and automotive and home technologies in the former Soviet Union, with emphasis on developments in Russia.

Science & Technology

EDITED BY CECILIA WESSNER

Space

Flying Reactors

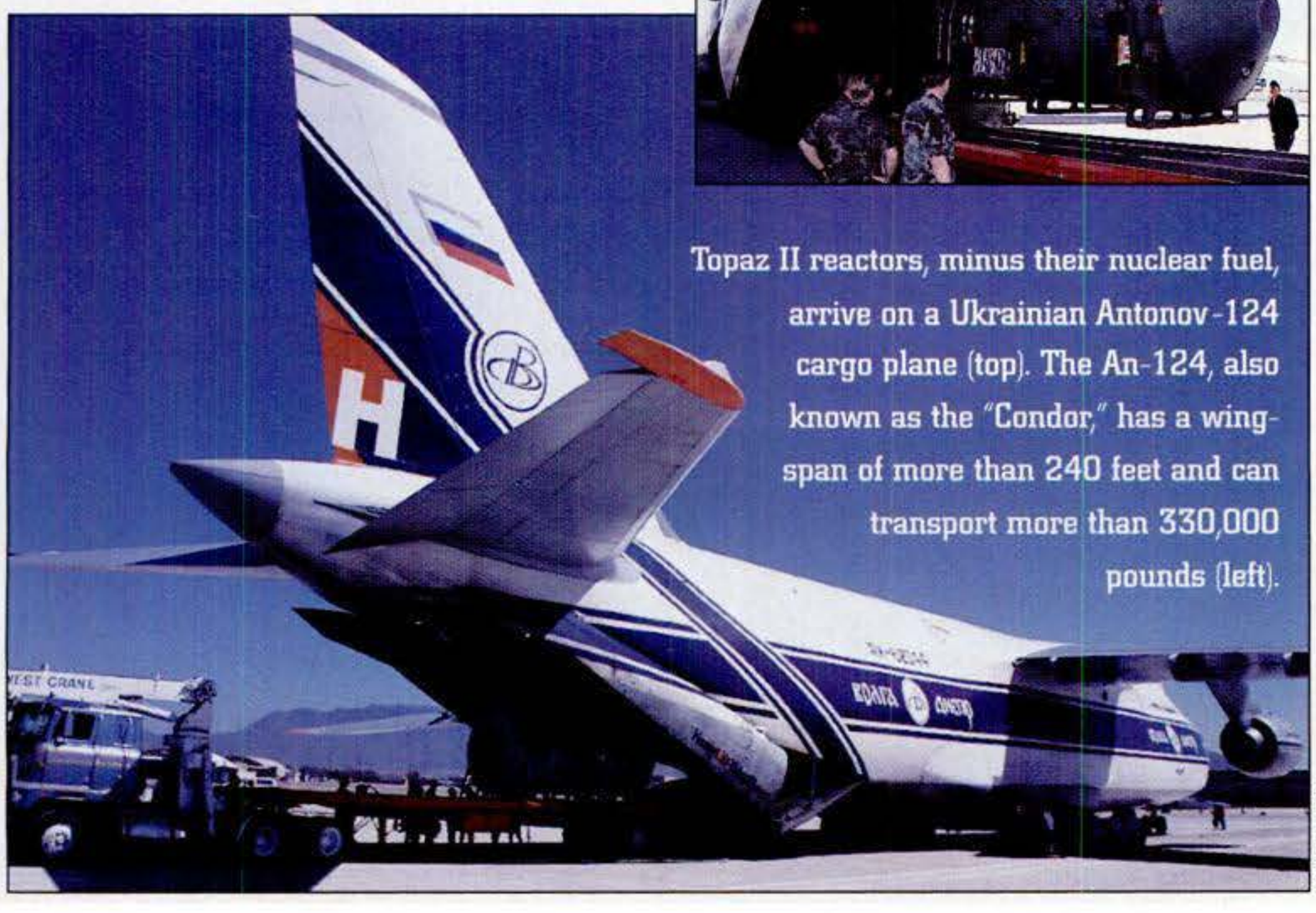
Four Russian Topaz II nuclear reactors for use in space have arrived at Kirtland Air Force Base in Albuquerque, N.M. They were flown from St. Petersburg in a gigantic Ukrainian Antonov-124 cargo plane. The reactors join two others that are now being tested at the University of New Mexico's Engineering Research Institute by Air Force researchers, aided by a team of engineers on loan from Russia.

The United States has not designed a space nuclear reactor in 25 years. Such a reactor would be far more powerful than the solar panels currently used by the U.S. for its spacecraft. The former Soviet Union maintained an active program, investing more than $20 billion in space reactors. The Air Force purchased the Russian reactors to help jump-start America's space nuclear effort.

Topaz reactors, used to power Soviet spy satellites in the 1980s, incorporate advanced alloys that can withstand temperatures of more than 3,000°F. The 6,000-watt reactors use highly efficient thermionic power generation; the power is produced when the intensely hot nuclear core emits electrically charged particles called thermions. The United States hopes to develop advanced thermionic reactors that could yield up to 40,000 watts of power for future satellites, both military and civilian.

In the U.S. test program, researchers use electric heaters to simulate the heat produced by the Topaz reactors. The reactors were delivered without their nuclear fuel.

Frank Thome, head of the Topaz test program, says that the two Russian reactors purchased in 1992 have been subjected to heavy wear in space simulations, and he's glad to have the four new reactors available for testing. "Two of the four are the latest and best [the Russians] have," he says. "They're flight-capable, so we will treat them with kid gloves." The Air Force hopes eventually to launch a Topaz for testing in space.—*Ray Nelson*



Topaz II reactors, minus their nuclear fuel, arrive on a Ukrainian Antonov-124 cargo plane (top). The An-124, also known as the "Condor," has a wingspan of more than 240 feet and can transport more than 330,000 pounds (left).

RAY NELSON

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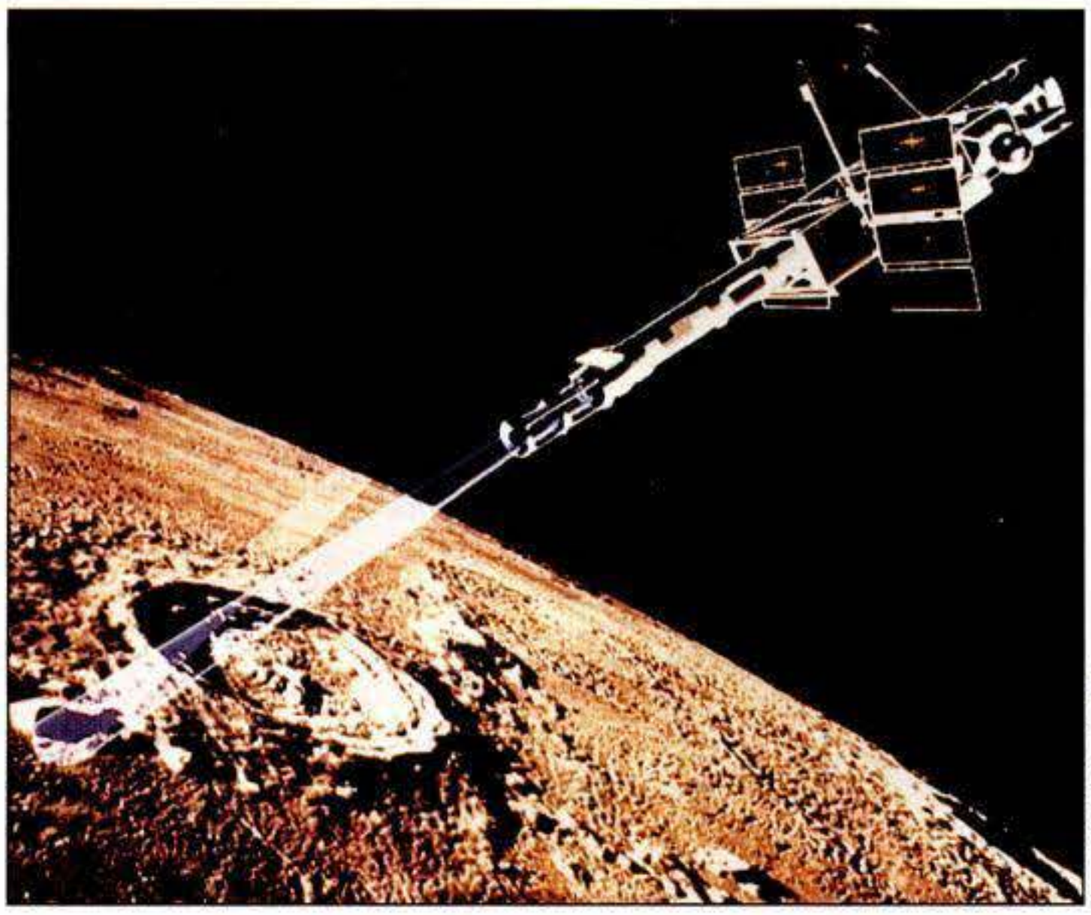
Geology

Probing The Moon's Surface

Take particle-beam technology originally created to zap Russian missiles. Put it inside a spacecraft built by McDonnell Douglas. Now blast the whole package into lunar orbit with a mammoth Russian Proton rocket. What do you have? A unique U.S.-Russian program for probing the geology of the lunar surface. Or at least that's the concept behind Northrop Grumman's proposed Double Eagle mission.



MCDONNELL DOUGLAS

Scientists hope to use a missile zapper to study lunar geology.

The year-long project, which could be launched early next century, is an effort to put to new use a particle beam device built by Grumman Aerospace (now Northrop Grumman) for the Reagan-era Star Wars program. Similar to the atom smashers used in physics experiments, Grumman's device accelerates protons to high speeds. But instead of crashing them into each other (or into a missile), the Double Eagle version of the accelerator would shower protons down onto the moon. They would penetrate the surface just deep enough to produce X rays that could be detected back on the spacecraft, allowing geologists to calculate the chemical composition of the moon's surface at that location. The high-resolution beam would enable researchers to investigate the formation of individual asteroid craters and canyons, for example.

As currently envisioned, the only Russian contribution would be a rocket powerful enough to lift the hefty accelerator. But Double Eagle's future is uncertain, because the Pentagon has slowed funding to a trickle, and NASA can't afford any new missions. To help it fly, Northrop Grumman hopes to redesign the mission over the next year, incorporating as many Russian spacecraft components as possible. This could pare one-third of the cost, now estimated at several hundred million dollars, according to program manager David Berwald.—*Robert Langreth*

Databases

Digital Toxic Avengers

A cleaner environment through computing." That could well be the motto of Russian and American scientists who will soon be swapping information and advice on cleaning up areas tainted by nuclear or chemical wastes, thanks to a new computer database system.

The system, dubbed EnviroTrade (Environmental Technologies for Remedial Actions Data Exchange), was developed at Sandia National Laboratories for the U.S. Department of Energy. It enables researchers to compile information about contaminated sites and the technologies used to detoxify or monitor them.

Once this data is entered, researchers in either country will be able to search quickly through thousands of environmental case studies to match current projects with other sites that are geographically similar—and choose the most effective technologies, based on experience. Currently, there are hundreds of contaminated areas across the former Soviet Union [see "Siberia at the Crossroads," this issue].

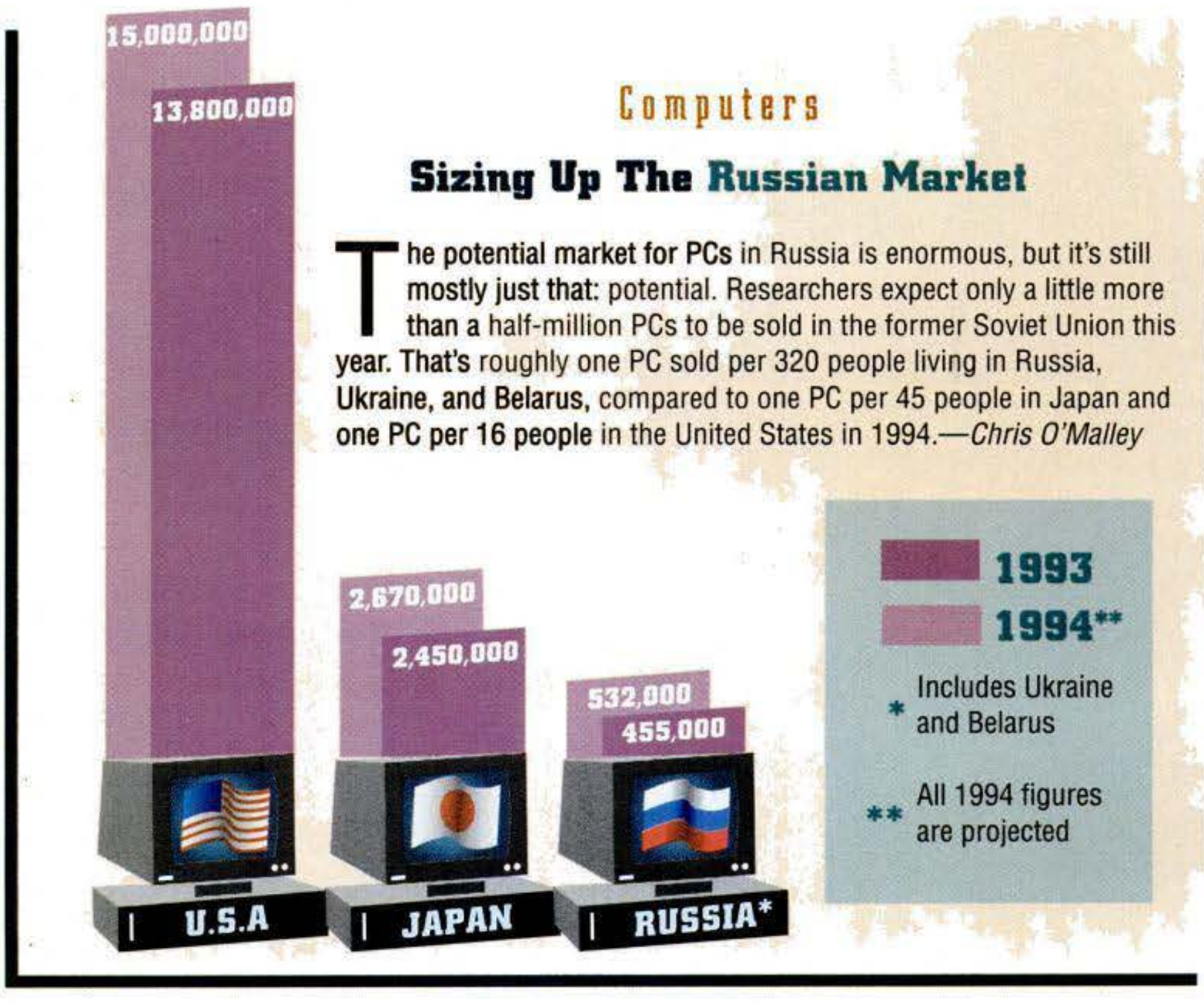
Sun Microsystems is providing five of its workstations to operate the database in Russia. Already, one EnviroTrade workstation is being used at a former nuclear weapons production site in the Ural mountains; three more were recently installed at scientific institutes in St. Petersburg, Chelyabinsk, and Moscow by Sandia researcher Mark Harrington. If negotiations pan out, two more workstations may be shipped over soon.

Scientists in the United States and Russia eventually hope to link their computers, possibly via satellite. Currently, the Russian and American parties share information using electronic mail, but that does not allow for direct access to the database. Videoconferencing is another future communications option.

In addition to expanding knowledge about environmental problems, the system should enable the researchers to cooperate on projects in real time—something they haven't been able to do before. And U.S. scientists hope to learn plenty from the joint venture: The Russians have already developed highly sophisticated mathematical algorithms to predict the movement of contaminants such as heavy metals and radionuclides in groundwater, for example, and EnviroTrade should allow Western scientists to evaluate these models and apply them to polluted areas in the United States. —*Judith Anne Gunther*

Computers

Sizing Up The Russian Market



NADINA S. SIMON

SOURCE: BIS STRATEGIC DECISIONS

The potential market for PCs in Russia is enormous, but it's still mostly just that: potential. Researchers expect only a little more than a half-million PCs to be sold in the former Soviet Union this year. **That's** roughly one PC sold per 320 people living in Russia, **Ukraine, and Belarus,** compared to one PC per 45 people in Japan and **one PC per 16 people** in the United States in 1994.—*Chris O'Malley*

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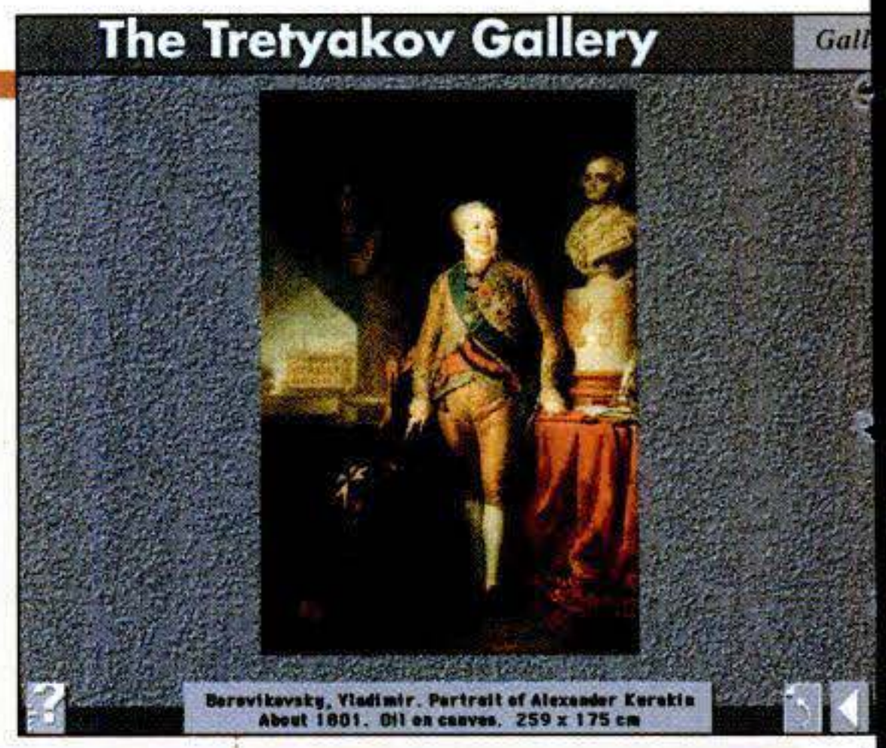
Multimedia

Digitizing The Masters

BY SANDY REED



"Alexander Kurakin" (right) and "Boatmen on the Volga" are two works on The Art Treasures of Russia, a multimedia CD-ROM.

Mark Lediard knew for sure that the technological and social climate in Russia was fundamentally changed when he was first approached by a group of Russian scientists. They weren't after military or scientific secrets; they didn't even ask Lediard for help acquiring American blue jeans. Did he, they wondered, know anything about creating CD-ROM discs?

It was the spring of 1993 and Lediard, a TV producer turned business consultant, was in Russia as part of a U.S. effort to gauge how average Russian citizens were reacting to government reforms. The Russian group seeking help with CD-ROM development called itself the Laboratory of Optical Telemetry (LOT) and was comprised of former military scientists, Lediard was told. More interesting still, the LOT group claimed to have acquired the electronic rights to every piece of art managed by the state of Russia—90,000 slides—and had decided to build a CD-ROM title around them.

Lediard thought it prudent to check the group out, especially given the legal safeguards in Russia—lax, by American standards. His snooping revealed that the group of half a dozen scientists were exactly who they said they were: solid citizens with a vision.

Lediard put the group in touch with RoundBook Publishing of Scotts Valley, Calif., a company which he has since joined as vice president of production. Now, just over a year later, the Russian "commercial opportunity" has become a bona fide product, a multimedia CD-ROM disc called The Art Treasures of Russia ($70). It is the result of a true joint venture, with LOT's scientists in charge of content, including the scanning of artwork and compiling of database information, and RoundBook creating the user interface and marketing the product.

The first step was to agree on a computer: RoundBook persuaded LOT to switch from IBM-compatible computers to Macintosh Quadras. The team then decided to develop the program using a multimedia toolkit called Macromind Director, which would enable them to release Macintosh and Windows versions simultaneously.

LOT's management team was loaded with scientific talent—advanced degrees from the Military Academy, Moscow Institute of Physics and Technology, and Moscow State University are the norm. Specialties include optics, infrared physics, computer modeling, and image processing. RoundBook supplied sorely needed marketing savvy. "LOT had no historical consumer habits [to rely on] because they never had to do anything with the consumer in mind," explains Lediard. Indeed, the scientists' first effort, which assumed that buyers of the CD-ROM would be highly sophisticated computer users like themselves, resulted in a product that was too difficult for even Lediard, a PC veteran, to use.

COURTESY ROUNDBOOK PUBLISHING

LOT president Vladimir Morozov (second from left) with his technical and sales team.

The final product is very much up to American multimedia standards. The Art Treasures of Russia, which was slated to be released this summer and should be available now, is an overview of Russian art. Many of its pieces, including historic photos and slides of paintings by Russian Realists and Impressionists, have been inaccessible to outsiders for decades. The disc also contains multimedia tours of major Russian museums, in which curators lead the user on video tours. Within each museum, individual works are highlighted, accompanied by narrated text.

Some of the works in The Art Treasures of Russia are traditional paintings by artists such as da Vinci, Matisse, Picasso, Renoir, and van Gogh. Others, such as those from the Kremlin museum, are slides of thrones and coaches used by the Russian czars, gifts to heads of state from centuries past, and, naturally, the much-coveted eggs crafted by the Fabergé firm of goldsmiths. Russia abandoned its system of centralized state control over all aspects of art in 1991. Custody of the slides of the official collections went to the USSR Academy of Art.

The Art Treasures of Russia is the venture's first effort, but not its last. Lediard anticipates that another half-dozen CD-ROM titles will be released over the next three years, with each disc containing images from 200 to 300 of LOT's 90,000 slides. Included in the slide collection are images from six major Russian museums (including the Hermitage, Pushkin, and Kremlin), plus photos of performing arts, such as the Bolshoi Ballet. The audio and text are in both Russian and English.

More Art On CD-ROM

The Russians aren't the only ones digitizing the masters. Other art collections are on CD-ROM as well.

Microsoft's Art Gallery ($80) features the art collection of the National Gallery in London. The National Gallery houses the British National Collection of Western European Painting, including more than 2,000 works from artists such as da Vinci, Michelangelo, Monet, and van Gogh. Art Gallery presents the masterpieces, basic descriptions of their origin, and animations that explore the techniques used by these great artists.

At least one other title preceded Art Gallery. Quanta Press (612-379-3956) sells a CD-ROM collection called Impressionism ($80), with 600 canvases from the likes of Cézanne, Manet, and Renoir. Quanta plans to offer similar collections called Abstract and Great Masters later this year or early next.—*C.O.*

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Communications

Russia On-Line

Frustrated with subpar telecommunications and postal systems, many Russians are turning to a newer and more reliable alternative: PCs and on-line services.

As elsewhere, the appeal of on-line connections in Russia is mainly the ability to exchange electronic mail, get the latest news, and sift through databases for information. But Russians have added incentives for getting on-line: E-mail is a more dependable medium than either phone calls or faxes in their country, since error-correcting PC modems can usually deliver messages intact despite the hissing and crackling of poor telephone lines. And on-line news services are more timely and have broader coverage than most newspapers and magazines—when you can get them delivered at all.

As a result, electronic bulletin boards and commercial on-line services are sprouting regularly in Moscow, St. Petersburg, and other urban areas. Relkom is Russia's largest on-line service, offering e-mail and bulletin board connections to about 200,000 users in most of the major cities of the former Soviet Union. That's a much smaller membership than U.S. services such as Prodigy and CompuServe, but it's an impressive total in a country where relatively few businesses, and even fewer consumers, own PCs.

Some services operate in English and connect with the West via e-mail on Internet. Glasnet, operating since 1990, is one such service. The subscriber numbers for these services are tiny by Western standards as well, but they are clearly having an impact on how Russia conducts business. It's increasingly common, for example, to see an Internet or Relkom e-mail address on Russian business cards. On-line services have had a major effect on government business too: During the attempted military coup in 1991, many Russians used their PCs to send e-mail to a worried world.—*C. O.*

The Moon

Lunar Landers

A San Diego company plans to offer launches to the moon, using Russian rockets and landers that are less expensive than their American counterparts.

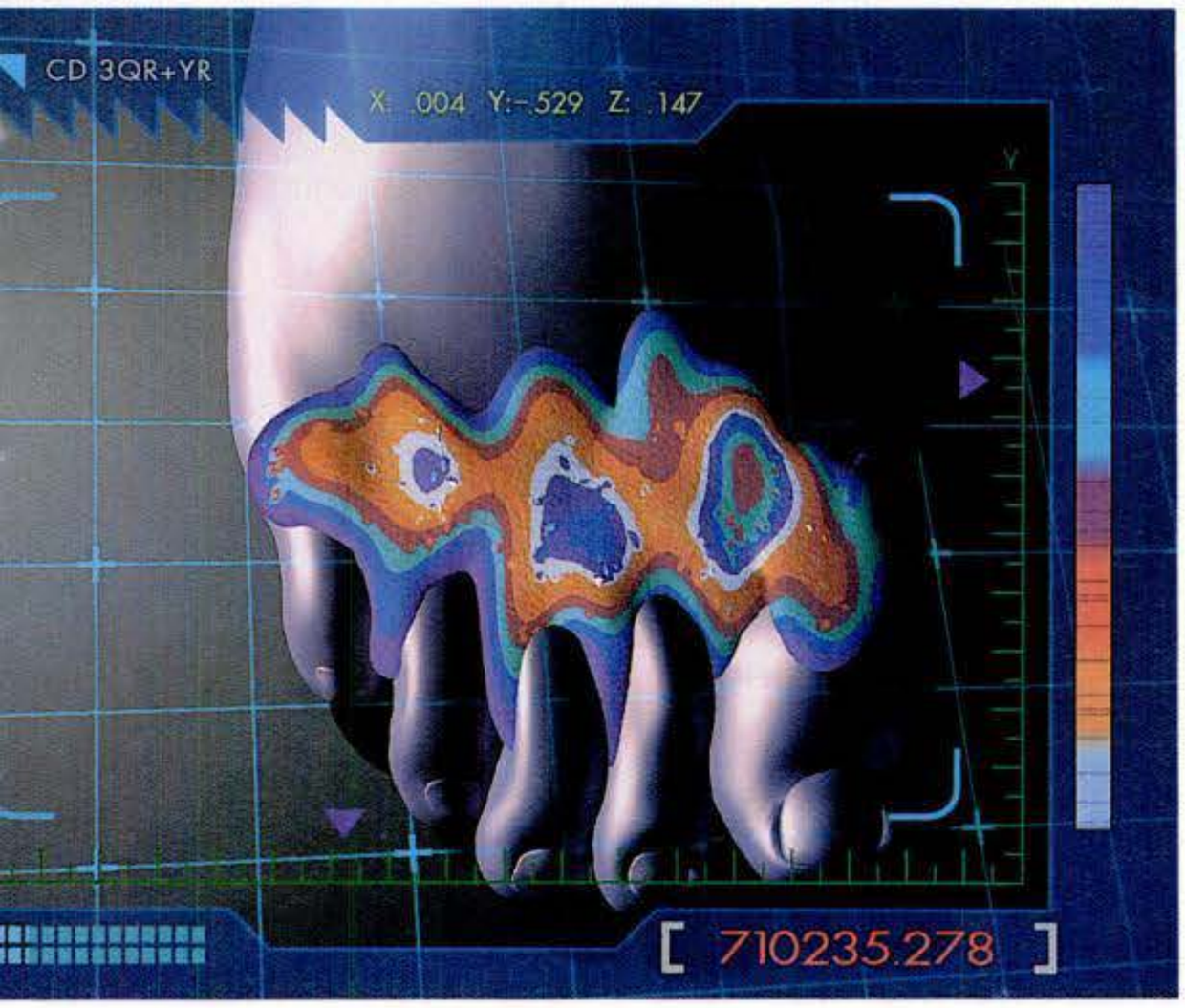
International Space Enterprises (ISE) estimates that the Russian launches will cost 80 to 90 percent less than conventional American launches. The first mission is scheduled for 1997, departing from a launch site at Baikonur in Kazakhstan.

Khrunichev Enterprises will build the powerful Proton rockets under a contract with ISE. Lavochkin Association, the Russian airplane and rocket manufacturer, will build the lunar landers and manage the missions.

"The moon is once again within reach," says Michael C. Simon, ISE's president. "We're selling tickets." Customers might include businesses that want to test concepts for mining the moon. ISE also is approaching scientists, and advertisers who could showcase a product on the moon.

ISE has already signed an agreement with LunaCorp of Arlington, Va., a company that wants to put a six-foot-long, remotely controlled rover on the moon. LunaCorp envisions a theme-park attraction that would allow people to drive the rover ["Electronics Newsfront," June].

John Pike, space policy analyst for the Federation of American Scientists, says the low cost of operations could make the business a success. "There are people who may become interested once they know the possibility exists," Pike says. "I didn't know ten years ago that I needed a fax machine, but now I depend on it."—*David Graham*



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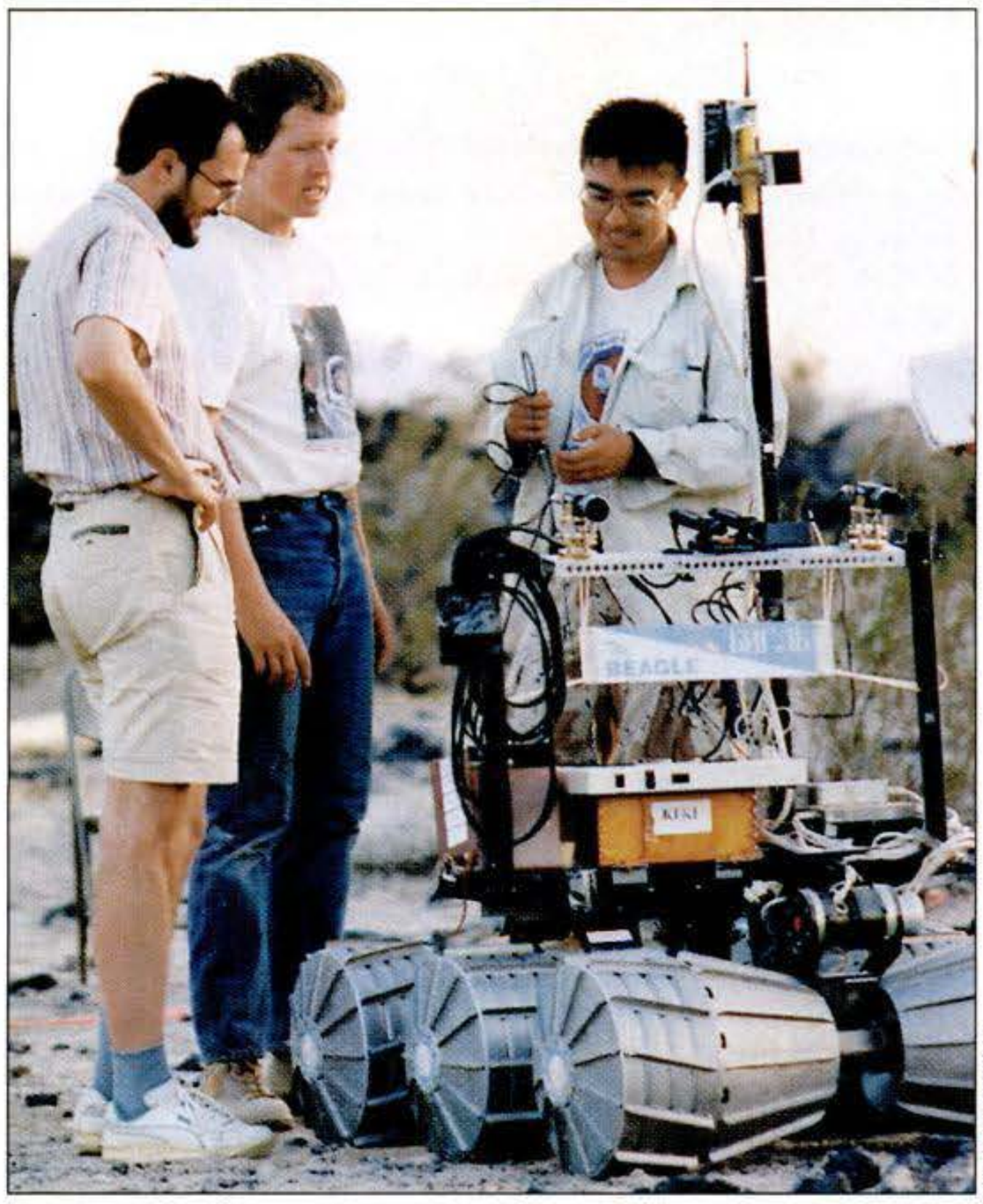
Mission To Mars

Where Are We?

An international space mission to be launched in 1998 will deliver a Russian-built rover to the surface of Mars. The vehicle will analyze rock and soil samples at as many sites as possible in a search for clues about the red planet's composition, and for evidence that some form of life may once have existed there. Caution will be the watchword for mission controllers back on Earth, whose greatest fear is getting their explorer stuck in a crevasse—a mishap that would curtail the robot's sampling work.

In late March, scientists and engineers from The Planetary Society, NASA, and three Russian space institutes gathered in a McDonnell Douglas Aerospace lab in Huntington Beach, Calif., to rehearse rover teleoperation, or joystick driving by remote control over long distances. About 200 miles away in the Mojave desert, the six-wheeled rover—named Beagle after Charles Darwin's ship—clambered over the jagged landscape around Amboy Crater, an ancient volcano with features that resemble the Martian terrain. Still pictures captured by the Beagle's stereoscopic video cameras arrived at the lab via satellite.



STUART F. BROWN

Driven by operators on Earth, the Beagle rover will explore Mars.

An imaging team assembled the arriving pictures into a mosaic. The team's task: Correlate the emerging mural with aerial photos of the crater to figure out the Beagle's location. Although the rover has on-board intelligence that helps it avoid obstacles, the best way to keep the vehicle out of trouble is by knowing precisely where it is. Then the operator can signal the Beagle to crawl forward, 25 feet at a time, with reasonable certainty that it won't get stuck. After each maneuver, the operator waits for updated pictures to appear on a stereoscopic headset. In the upcoming mission, communications will require eight to 40 minutes to make the round trip between Earth and Mars, depending on the planets' positions.

The two Viking landers that arrived on Mars in 1976 touched down in unexpectedly rocky areas and were lucky not to have tipped over. The Viking orbiters had extensively photographed the planet's surface before dispatching the landers, but the orbiters' cameras weren't good enough to spot the rocks.

Higher-resolution cameras aboard the future Mars orbiter will deliver images of potential landing locations in greater detail. As the lander descends, it will correct its course in search of a hospitable touchdown site, similar to how a cruise missile navigates by comparing the terrain beneath it with a map stored in its computer memory. The lander will also take snapshots of the approaching surface, and the imaging team will use these pictures to answer the question: Where the heck are we?—*Stuart F. Brown*

Aviation

Safer Skies

Travelers were recently advised not to fly over the former Soviet Union because of its decaying air-traffic infrastructure. Now a Russian military producer is teaming up with Westinghouse Corp. to make flying safer. Together, they will create a highly accurate air-traffic-control radar system that combines Russian hardware with Westinghouse software and other components.

Russia's All Union Scientific Research Institute of Radio Equipment and Baltimore-based Westinghouse plan to demonstrate the system at the Polkava Airport in St. Petersburg by next year. Production could begin by 1996.

The project will use a Russian version of monopulse secondary surveillance radar, which emits a signal to communicate with an aircraft transponder. The transponder, in turn, reports the plane's identification number, along with its altitude and its location in the sky. A Westinghouse processor and interface software will control the system.

The resulting radar will have a unique capability: Russia and other Eastern nations have traditionally used a different radio frequency than that used in the West. The new radar system will work with both frequencies.—*Mariette DiChristina*

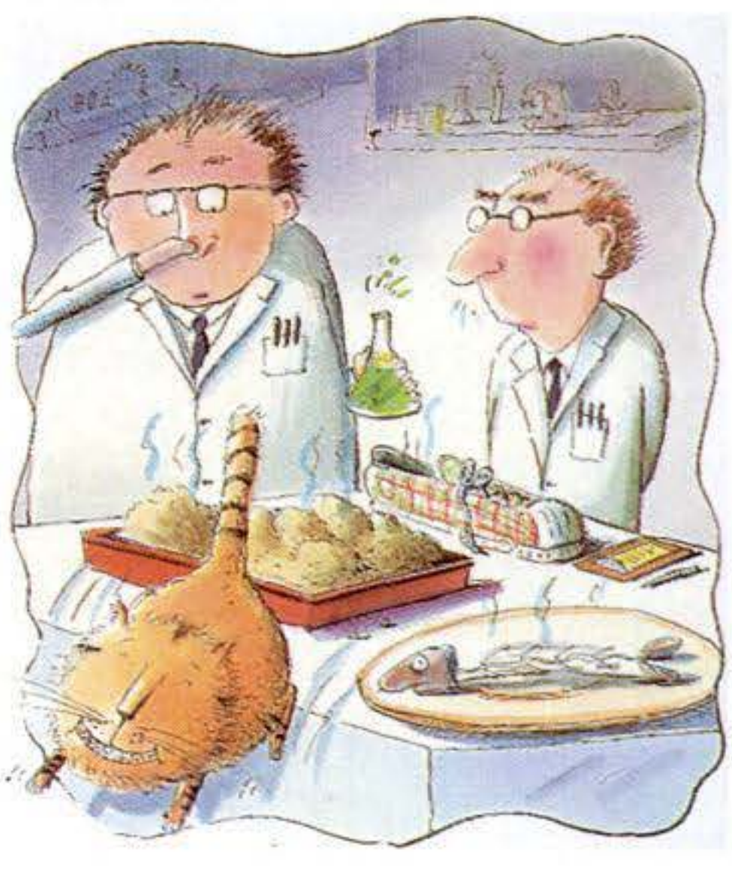
Chemistry

Odor Beater

Ever wonder why dirty socks and rotten eggs smell bad? It's the mercaptans—hydrogen sulfide molecules. With today's best technology, carbon filters, you can remove five percent of these molecules. But soon 95 percent of the odor will be eliminated by a catalytic deodorizer, accidentally discovered by scientists at Niopik, a Russian laser dye laboratory.

The catalyst is phtalocyanine, a compound that causes hydrogen sulfides to oxidize and turn into water, carbon dioxide, and odorless forms of sulfur. Phtalocyanine has long been known to have this property, but scientists didn't know how to stabilize it on a carrier—such as a shoe sole, diaper lining, or kitty litter.

When phtalocyanine is in an alkaline state, it can be spread thinly on a carrier for maximum effectiveness. But acidic conditions make the phtalocyanine contract into a ball. The Russian scientists discovered a way to make carbon-based materials that can maintain the alkaline environment the phtalocyanine needs. Colgate Palmolive, Proctor & Gamble, and 3M have expressed interest in licensing the technology.—*Suzanne Kantra*



DEBBIE TILLEY

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Hardware

Joint Maneuvers

A clever hinge gives doors the flexibility of a contortionist—and is invisible to boot. Developed by Russians Anatoly Gleb and Igor Esman, the hinge enables doors to open in both directions and fold flat against either adjacent wall.

How does it work? Inside the hinge are two levers; both are mounted on pivots at each end. When the door is closed, one lever crosses the other in an "X" shape. As the door is opened, both levers rotate on the pivots until they align, one over the other. As a result, the door travels in an elliptical arc, not a semicircle.

Because the hinge is recessed into cuts in the edge of the door and door frame, where it is secured by screws, it is completely hidden from view. It is available in several versions for different joint styles, materials, and load requirements. The hinge offers a sleek, aesthetically pleasing alternative to conventional hinges for kitchen cabinetry, furniture, decorative screens, and interior doors such as those leading to a butler's pantry.

Although the hinge is being marketed in Russia through Atlas City, a Moscow-based company, it is not currently for sale in the United States. —*David Scott and J. A. G.*

Materials

Ceramics That Beat The Heat

The most prestigious materials-research center in the former Soviet Union plans to market two unique new compounds that could lead to more fuel-efficient cars, trucks, and airplanes.

The Institute for Problems of Materials Science (IMPS), a 3,500-researcher megalaboratory in Kiev, Ukraine, has developed a new type of ceramic composite that could prove useful in diesel engines.

Engine makers have long been fascinated by ceramics because they can withstand higher temperatures than metal; at hotter temperatures, fuel burns more efficiently. The hitch: Ceramics are brittle, making them less than ideal for high-stress environments like engines.

But the laboratory says it has formulated a silicon-titanium composite that retains its strength at the temperatures produced by a diesel engine, and, in fact, up to 900°C—well above temperatures metal can withstand. Although officials from Emtech, the Toronto-based company marketing the material, are keeping the exact composition of the ceramic secret, they say the material is currently being tested by a major manufacturer of diesel engines.

The Ukrainian Institute also operates the only scandium mine in the world. Using the supply of this extremely rare metal, the institute has created and patented several unique aluminum alloys that it claims are stiffer than all existing alloys of aluminum, but just as lightweight. Through Emtech, it will soon start selling the alloys to Western buyers.

If they live up to their billing, the new metals would be ideal for building lighter or more durable jet aircraft; this is important because every extra pound added to a jet boosts fuel costs tremendously—and decreases performance. They also could allow car makers to use more aluminum, say aluminum industry experts. This would help reduce vehicle weight—and hence boost gas mileage.—*R. L.*

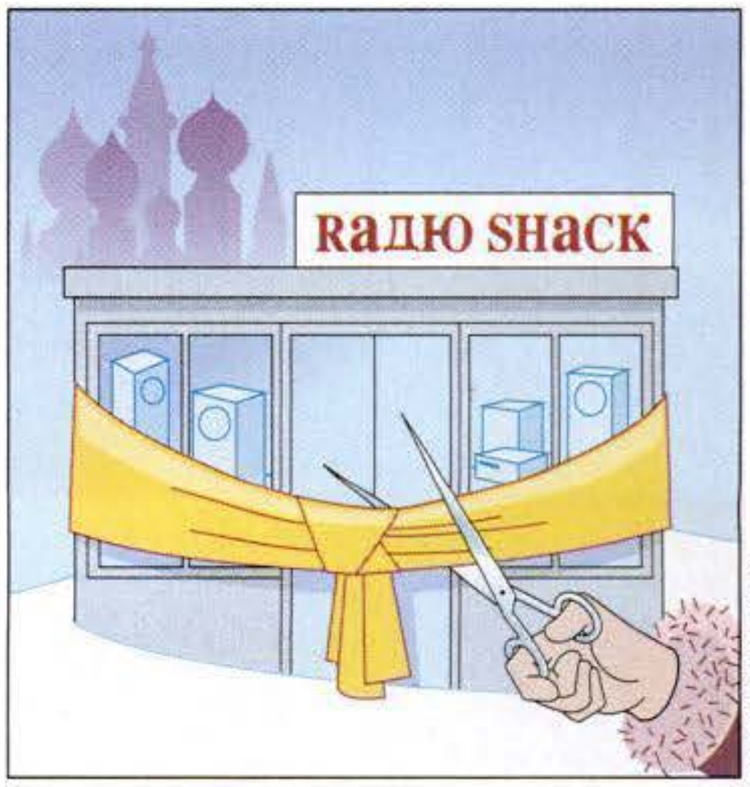
Home Electronics

Radio Shack Goes To Russia

Set back from Moscow's Leninsky Prospect, an eight-lane boulevard in a neighborhood of science academies and apartment buildings, stands a landmark to consumerism: the first Radio Shack franchise in Russia. Occupying two levels behind a large window, the 25,000-square-foot store opened this past New Year's Eve.

Unlike other stores in Russia, merchandise isn't kept behind locked counters. The store stocks some 3,400 products ranging from resistors to television sets to multimedia computers. The diversity and abundance of such products under one roof, rare in Russia, appeals to both hobbyists and affluent consumers.

Manager Steve Williams says that though his shop's prices are necessarily about 30 percent higher than those at Radio Shack stores in the United States, prices for the same items elsewhere in Moscow are typically marked up even more.



STEVE STANKIEWICZ

In the first five months of operation, he says, the most popular sellers have been telephones and phone accessories, car stereos, videocassette recorders, car alarms, boom boxes with CD/cassette players, and all kinds of batteries. One woman who had trouble finding watch batteries brought in 12 timepieces to be rejuvenated.

Prices are posted in dollars because signs in rubles would have to be changed every few days to keep up with inflation, says Williams. The franchise Radio Shack is wholly owned by the Florida-based Trident Corp., which plans to open other Radio Shacks in Russia.

The store has yet to do any advertising. Williams says, "The word of mouth is extraordinary."—*Michael Antonoff*

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Optics

Tracking Space Debris

A Russian technology for tracking missiles may soon be used to spot orbiting objects as small as one centimeter in diameter and as far away as 1,000 kilometers. Current systems cannot detect space debris smaller than ten centimeters across.

Called optical phase conjugation, the tracking system bounces a laser beam off faraway objects. Normally, ripples in the atmosphere distort the reflected signal. But the Russians use a mirror, made from pressurized gas or ultrapure liquid, to correct these distortions.

Russian researchers are at least five years ahead of U.S. scientists in the development of tracking systems that employ high-energy laser pulses. To catch up, the Idaho National Engineering Laboratory and the Air Force are paying the Russians to demonstrate their technology. It could also be used to detect environmental contaminants in the atmosphere.—*Dawn Stover*

Radar

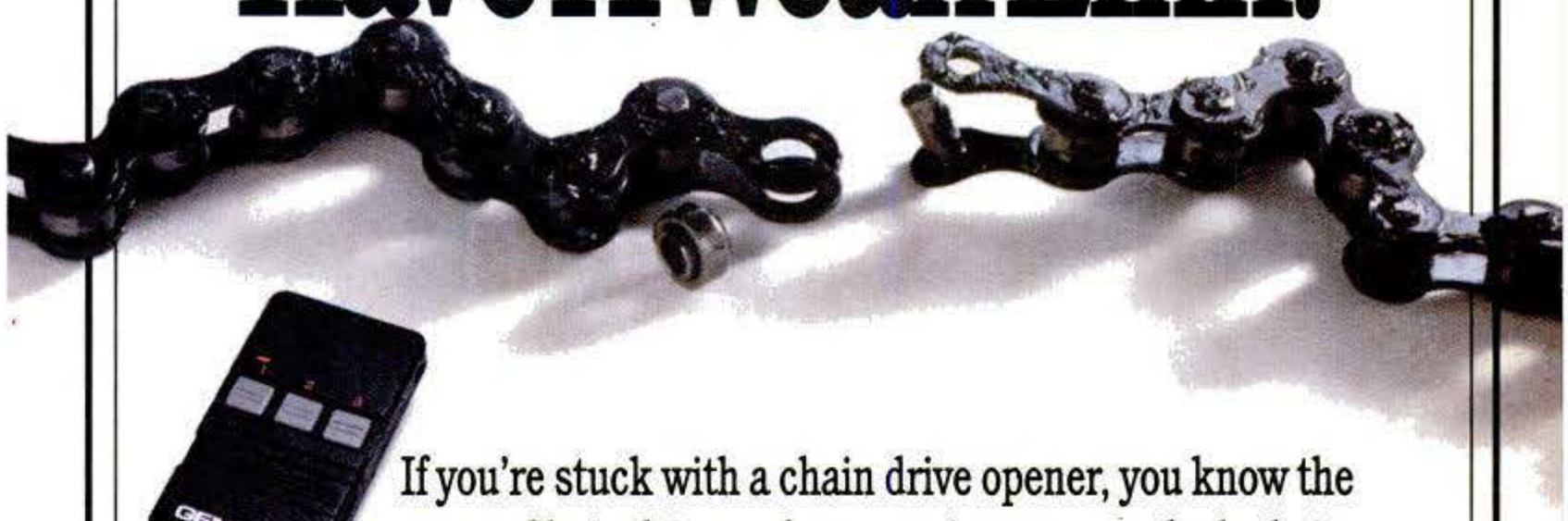
Deep Vision

Russian researchers, like their American counterparts, are anxiously searching for ways to commercialize military technologies. A St. Petersburg company that produces radar systems may become one of Russia's first defense-conversion success stories.

Leninets Association has developed radar that can locate, from a plane, objects buried up to 99 feet underground. Among the applications: Geologists could use the radar to map mineral resources, and engineers could assess conditions for road construction and pipeline installation. The radar's closest rival is a system developed in the United States that can penetrate no deeper than 28 inches, claims Leninets vice president Yevgeny Guryanov.

The Oman Oil Company is eager to use the new radar to construct an oil pipeline that would join the former Soviet republic of Kazakhstan with the United Arab Emirates. But because Leninets is short of development funds, the radar remains untested. It may take another $3 million to develop and test the system fully. —*Wordservice International* PS

Does Your Garage Door Opener Have A Weak Link?



If you're stuck with a chain drive opener, you know the answer. Chain drives rely on a noisy, greasy, slack chain with hundreds of little links that can stretch or even break. Consider the advantages of installing a Genie® Screw Drive Opener:

Increased Strength. Unlike most chain drive openers, Genie's solid ten-foot steel screw and direct-drive technology deliver more lifting force to your door.

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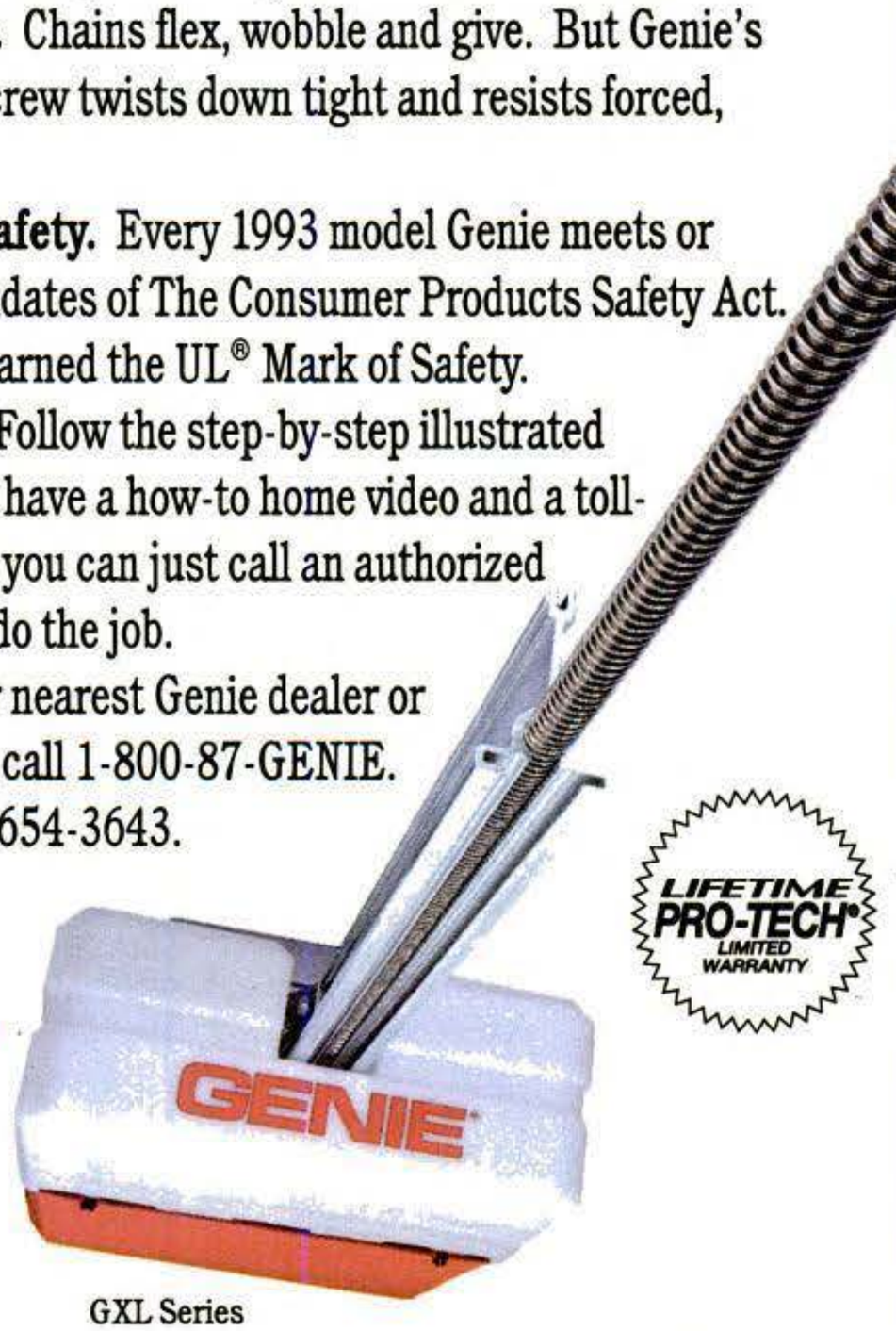

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COUNTERPOINT

The demise of the $11 billion Superconducting Super Collider in the United States also had ramifications for Russia's scientific community. Twelve Russian institutes were contracted to supply $50 million worth of equipment to the SSC project, a substantial source of hard currency. Fortunately for them, the Russian physicists who would have contributed to the SSC signed an agreement last October with CERN, the Geneva-based particle physics center. The deal may allow them to supply hardware and services to what would be the world's largest atom smasher.

Moscow

Soviet scientists and engineers won Nobel Prizes and pioneered space exploration. Now, they are struggling for existence.

The Russians are playing with a different set of rules these days. It's called "anything goes." And it's devastating the country's once-lofty science and technology establishment.

The rules changed with the breakup of the old Soviet Empire, beginning in December 1991, and the simultaneous abandonment of the weapons race that was the legacy of the Cold War. The result is a second Russian revolution 77 years after the first, with attendant political, social, and economic chaos.

Signs of chaos were obvious when I visited Moscow last April. It was like a trip to the Barbary Coast, where piracy reigned and absolutely anything—and almost anybody—could be bought, if you had enough hard cash.

It was a Moscow that had been transformed into the world's largest flea market, where flimsy street kiosks filled with imported camcorders, video games, and portable TVs are guarded against theft by thugs for a mere 20 percent of sales. Where a new Cadillac Fleetwood, sold off the floor of what was once a department store called "Children's World," goes for $74,000. Where a Moscow health committee warned against an outbreak of trichinosis from contaminated pork sold in the city's open-air street markets. Where organized crime controls or extorts money from 50 to 80 percent of private shops and businesses, including the 2,000 or so banks that have sprouted in Moscow during the last few years. Where entrepreneurs become overnight millionaires by illegally selling state property. Where, as one Muscovite told me, "everyone wants to buy and sell, but no one wants to make anything." Where 30 percent of the population lives in poverty.

This second revolution has undercut many assumptions of Russian life, none more so than the primacy of the vast scientific and technological enterprise, which once numbered a million

BY ARTHUR FISHER

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Bulgs

members. Of that number, 30,000 have emigrated to Israel, thousands more to the United States and Europe. Perhaps 200,000 have opted for "internal emigration," quitting their jobs but remaining inside Russia. Of the 100 scientists most frequently cited in scientific journals in 1990 (and therefore the cream of the crop), at least half now have permanent jobs outside Russia. There is no money left in Russia for science.

The dangers of this kind of decimation and the throttling of Russian science are grave. The virtual abandonment of many nuclear scientists and engineers by the state has created a desperate class of drifters capable of exporting their weapons expertise—and even, with the help of organized crime, bomb materials—to outlaw regimes (see "Nuclear Chaos").

More fundamental is the price America—and the world—would pay for the death of Russian science. Over the years, that huge enterprise (the Russian Academy of Sciences controls more than 300 basic research institutes) has contributed to every country's well-being by advancing civilization's state of knowledge of our planet and of the solar system we live in. Soviet scientists have garnered eight Nobel Prizes in physics, chemistry, and medicine and physiology. Soviet engineers have advanced the arts of communication and space exploration.

Now this once-mighty engine for knowledge has been humbled, its rich potential for future contributions to the world's welfare threatened.

"Civilization would be much poorer without Russian science," says Nobel laureate Leon Lederman, Director Emeritus of the Department of Energy's Fermi National Laboratory. "Apart from outstanding discoveries in

The collapse of the Soviet Empire begun under Mikhail Gorbachev and completed under Boris Yeltsin has devastated Russian science and technology.

JOHN B. CARNETT

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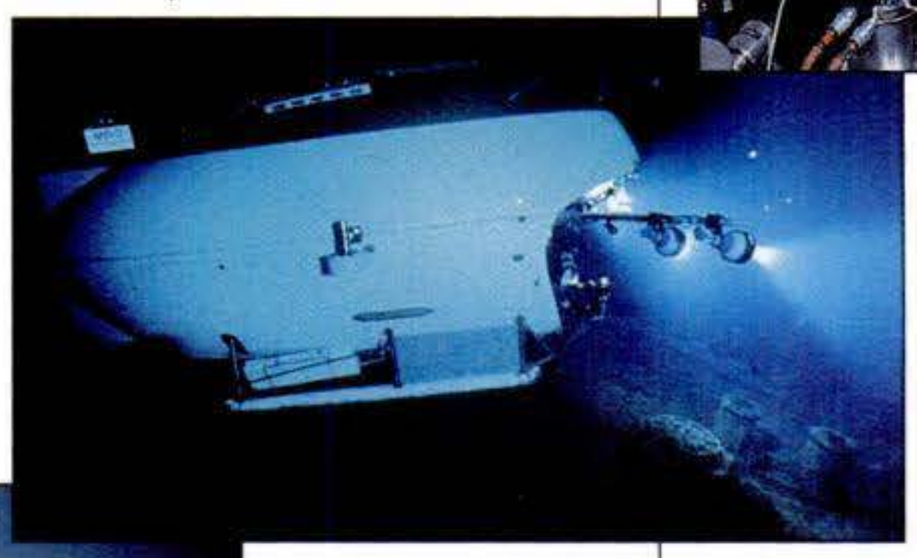
disciplines ranging from space to biology to particle physics to mathematics, Russian scientists provide the kind of intellectual stimulation and fertilization of ideas that makes science a global community."

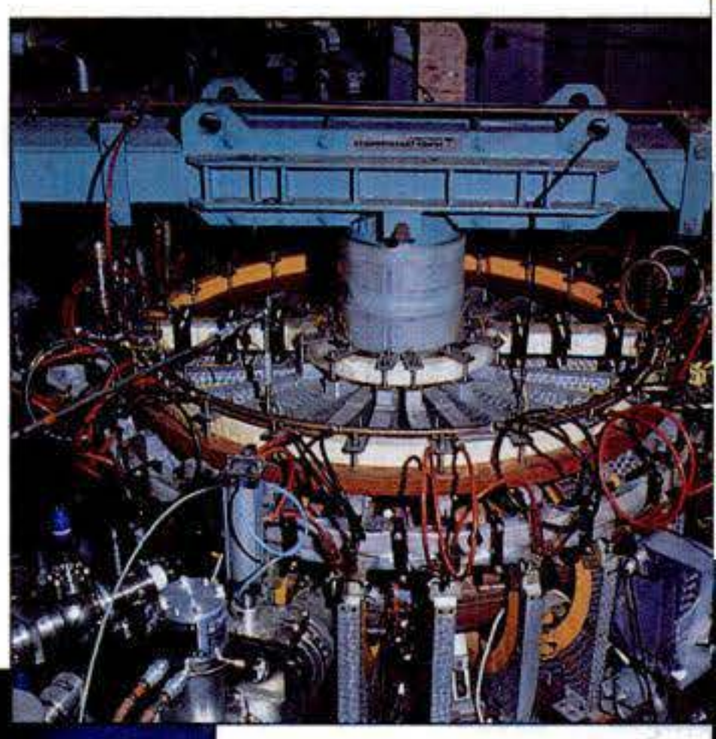
Russian scientists are forming international partnerships in areas where they have special expertise: lasers, fiber optics, oceanography, fusion, and marine biology.

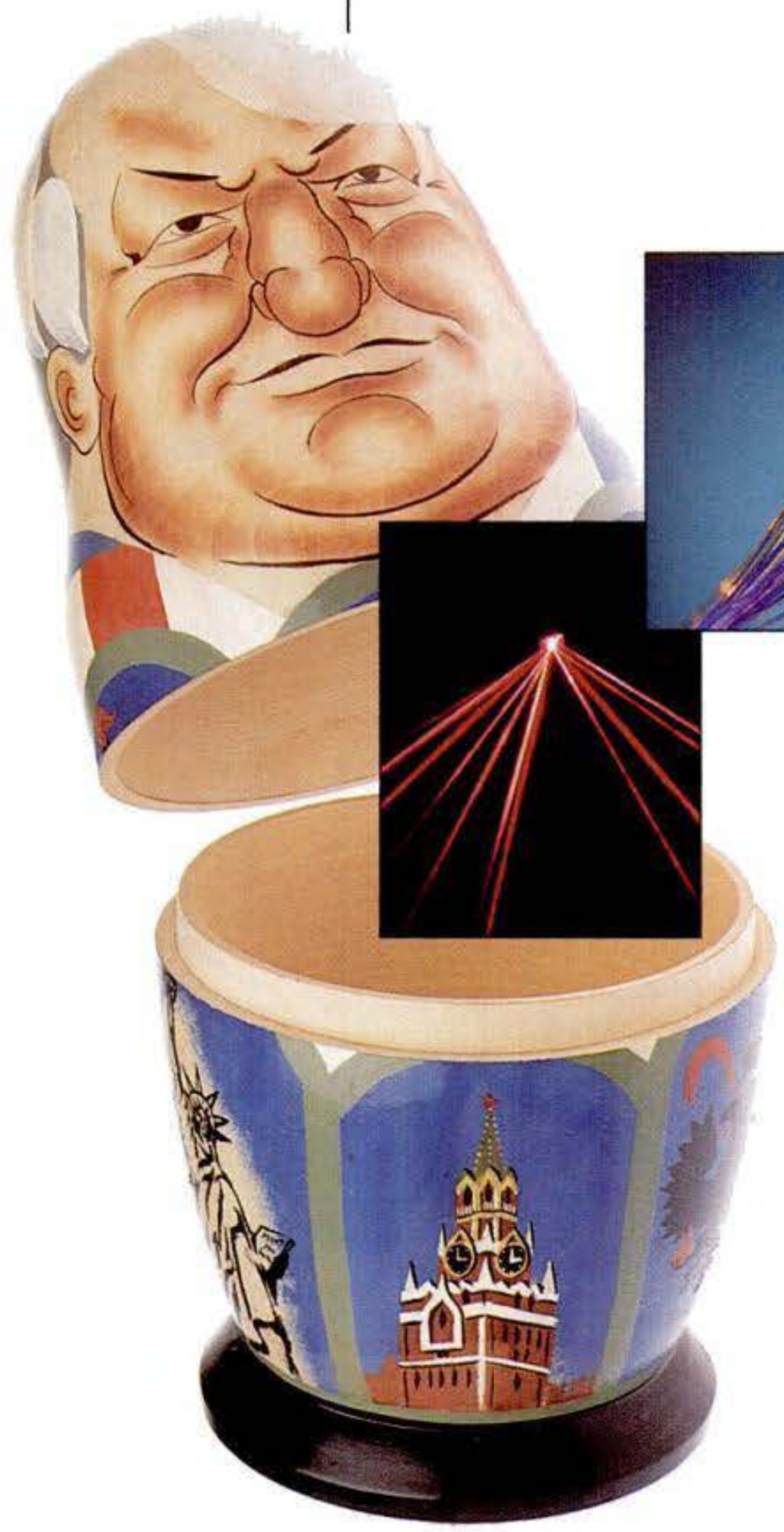
Examples abound: The tokamak device is the United States' leading candidate for a practical fusion energy machine; *tokamak* is a Russian word, and the tokamak design was invented at Moscow's Kurchatov Institute. Lasers are now ubiquitous, found in everything from CD players to periodontists' offices; Russian physicists were awarded the Nobel Prize in 1964 for fundamental laser research. And the Russian-invented "Siberian snake" is a device used in high-energy physics to enhance synchrotron radiation, used to X-ray equipment components and welds.

"Now high-energy physics in Russia is essentially wiped out," says Roald Sagdeev, a Russian plasma physicist who was once high in the councils of the Soviet government and served as director of Moscow's Space Research Institute for 15 years. Sagdeev now teaches at the University of Maryland (see "How the Soviets Got the Bomb"). "What we have left," he says, "is the network of institutes. They are completely dependent, financially and in every other way, on their chance to participate as junior partners in international projects."

Contributing to the woes of high-energy physicists is the soaring cost of electricity, which has multiplied fifteen-fold just since the start of 1993. As a result, many facilities simply cannot afford to run their experiments, which typically gobble huge amounts of electrical energy. The Institute of High Energy Physics in Protvino has enough funding to energize its accelerator for only two or three weeks in each calendar quarter. Full-time use would leave no money for physicists' salaries. Some of the monthly electricity bills actually exceed the total state budget allotted to the institutes for that period. In March, Boris Saltykov, head of the Ministry of Science and Technology, announced that 50 such institutes would have to pay only half of their debilitating bills for electricity. But that left another 270 institutes in the lurch.







Sagdeev is not optimistic about other scientific sectors. "We see the same picture across the whole spectrum of disciplines," he says.

For example, the Russian aerospace community lost approximately two-thirds of its budget in the upheaval. "You can follow the decline of the Russian space program by counting the number of launches," Sagdeev says. "At the peak a few years ago, Russia was launching more than 150 spacecraft and space probes annually, the United States 100. Russia was launching cheaper, simpler, short-lived spacecraft to compensate for the more sophisticated and almost immortal American spacecraft like *Voyager*. Now the number of launches has dropped to about one-third of the previous total."

However, says Sagdeev, the biggest loss may have been sustained by the Russian computer and electronics industry. On top of the breakdown in the budget, at the end of the Cold War in 1990 Russia was immediately flooded with foreign-made computers, mostly PCs. Russian domestic computers, backward compared with those produced in the rest of the world, were immediately wiped out. "There was no more need for research in microelectronics," he says, because the Russians were hopelessly far behind "and huge crowds of experts in software, for example, now hope only to get contracts from United States companies or even the U.S. government."

Indeed, I learned that the only potential for salvation for Russian scientists and engineers lies in cooperative ventures with the United States and other countries, where the payoff for Russians is sustenance, and the payoff for their partners is special knowledge and expertise.

Without the funds that flowed from the massive military-industrial complex of Soviet times, scientists and engineers are scrambling to keep their research—and themselves—alive.

JOHN B. CARNETT / PHOTOTAKE / IMAX

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"There are three basic causes for the present problems of Russian science," Saltykov told me. "The first is lack of money. The second is lack of money. And the third is lack of money.

"In the first half of 1992 we dramatically changed the structure of economics and society—one of the main changes was demilitarization. Orders—and payments—from the military to industry and science dropped by more than half. Maybe it was a mistake to impose such budget reductions on the science community, which is huge and complicated. Maybe we pressed too hard. Even the Academy of Sciences, which conducts mostly basic research, received a third of its budget from the military."

Total government spending on science dropped from six percent of gross national product in 1991 to three percent in 1993, and the GNP has been dropping steadily since 1991. Scientific institutes that were heavily involved in defense work were hit much harder than even these figures imply; funding for such work declined 80 percent from 1991 to 1992. The 1993 science budget was about 800 million dollars, and Saltykov said it would remain at that level for at least the first part of 1994. (The total U.S. research and development budget for 1994 is about $68 *billion*, including $36 billion in the Defense Department budget.) Research is almost at a standstill at many facilities, Saltykov said.

"Our first goal is to prevent our scientific potential from being destroyed, especially our ability to do basic science. It's not only in Russia's interest to save Russian science, because it's a real treasure chest for the whole world."

The plight of scientists in Russia today is desperate; salaries are often below those of unskilled workers. "Russian scientists now have to be almost more worried about buying bread and milk for their families than about their own work," Saltykov told me.

Some members of the Russian Academy of Sciences earn $6 a month. At the Institute of Theoretical Biophysics in Pushchino, a city 60 miles from Moscow that is home to eight research institutes in chemistry and life sciences, scientists earn around $10 a month. To eke out this salary, some pick potatoes. For every ten sacks they pick, they can keep one, and three sacks is worth a month's salary. Frank Starmer, a Duke University scientist who worked with members of the institute, reported that "about $20,000 a year would support three senior investigators, six postdoctoral students, and support staff and assistants."

At the Institute of Organic Chemistry in Moscow, scientists' salaries averaged about 20,000 rubles a month in mid-1993, perhaps $13. Workers who cleaned Moscow's subway system got 22,000 rubles.

At some institutions, a senior physics researcher earns $12 a month, less than what a bus driver makes—and the buses don't even run on time.

And at Akademgorodok, a science enclave in the Siberian city of Novosibirsk, even a full professor got a salary of just $40 a month in January 1994.

Frequent shortages of hard cash have forced the once-cosseted scientists at the weapons labs of Arzamas-16 and Chelyabinsk-70 to scrounge for food. A worker in a civilian laboratory was paid a month's wages in vacuum cleaners. To raise enough money to live on, he joined the other flea-market vendors in Moscow's underground passageways.

As a result of this financial squeeze, some scientists and engineers simply leave their occupations but stay in Russia to find more lucrative careers, like a computer programmer who left a prestigious institute to get a job programming sewing machines in a blue jeans factory. Almost half of the employees of that division have left, says its head, Boris Babaian (see "Computer Czar.")

Other scientists have sought a variety of ways to supplement their income, ranging from the pedestrian to the enlightened. Some drive cabs, or sell vodka. Yuri Tamburenko, a spacecraft designer, told me he now works only part-time for Moscow's Space Research Institute. The rest of the time he spends in the United States working for Loral Space Systems.

Vladimir Vlasenkov spent a dozen years at the Kurchatov Institute in Moscow, a center for fusion research. Now he is scientific secretary of ITER (International Thermonuclear Experimental Reactor), the consortium for a future fusion reactor. But he has also become a businessman, promoting the distribution of American books, such as the various *Time-Life* series. On top of everything else, he has become the Moscow representative of an international literary agency, Lynn C. Franklin Associates, Ltd.

"In today's Russia," he said, while proudly showing me cupboards filled with American books, "you have to make your opportunities. The trouble is that so many scientists and other people knew only how to take orders. Now those people are lost."

The most promising route to self-sufficiency for Russian scientists is to form mutually profitable commercial agreements with foreign companies, especially in the United States. Boris Babaian's arrangement with Sun Microsystems is a paramount example; there are many others.

The Budker Institute of Nuclear Physics in Novosibirsk has sold $250,000 of equipment to Duke University's John Madey, inventor of the free-electron laser, for use in his experiments. The hardware, Madey says, was "unavailable from any other source at any price." Madey is trying to raise half a million dollars to ship Budker's free-electron laser, the OK-4, to Duke, and to pay three years' worth of salaries for Russian laser experts to operate it.

One spectacular example of such East-West collaboration was the Russian-American-Canadian IMAX/Titanic '91 Expedition, which was led by Anatoly Sagalevich of Moscow's P.P. Shirshov Institute of Oceanology. Besides collecting valuable scientific information, the trip resulted in the Toronto-based IMAX Corp.'s film of the sunken

[*Continued on page 78*]

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COUNTERPOINT

At first designated the Manhattan Engineer District by the U.S. War Department, the Manhattan Project (also known as Project Y), whose purpose was to design and produce an atomic bomb, was located at a site occupied until 1942 by the Los Alamos School for Boys in the Jemez mountains of New Mexico. After World War II, the Los Alamos Scientific Laboratory, operated by the University of California for the Atomic Energy Commission, developed the H-bomb. The secret city of Los Alamos became "open" in 1957.

How the Soviets Got the Bomb

With roaring fire and flashing flight of steel, tank men will carry out violent attacks, when orders come from Comrade Stalin.
—Soviet patriotic song

Long before the tanks of the Red Army entered besieged Berlin, Josef Stalin knew that the era of the tank men was over. Soviet espionage networks in the United States and the United Kingdom had already started to send messages about the Manhattan Project to build an atomic bomb, and even descriptions of an early design for a plutonium bomb.

Stalin needed the bomb desperately. With the first American test explosion at Trinity site in the Alamogordo Desert on July 16, 1945, the international race to build the first nuclear weapon was lost to the United States.

The Soviet efforts to establish a nuclear program—a massive effort comparable to the American Manhattan Project—started in the winter of 1943, when the government brought several scientists and leaders of military industry to the Kremlin to meet. At that moment, Stalin chose Igor Kurchatov to lead the project.

Kurchatov represented Stalin's quest for the "new man" of sci-

Some who made the Soviet H- and A-bombs: Clockwise from top: Andrei Sakharov, Igor Kurchatov, Yuly Khariton, Lavrenti Beria.

TOM WHITE / ROBERT DEL TREDICI / AP / WIDE WORLD

Which contributed more to the creation of the Soviet Union's nuclear weapons—science or espionage? An eminent Russian physicist untangles the controversy.

BY ROALD SAGDEEV

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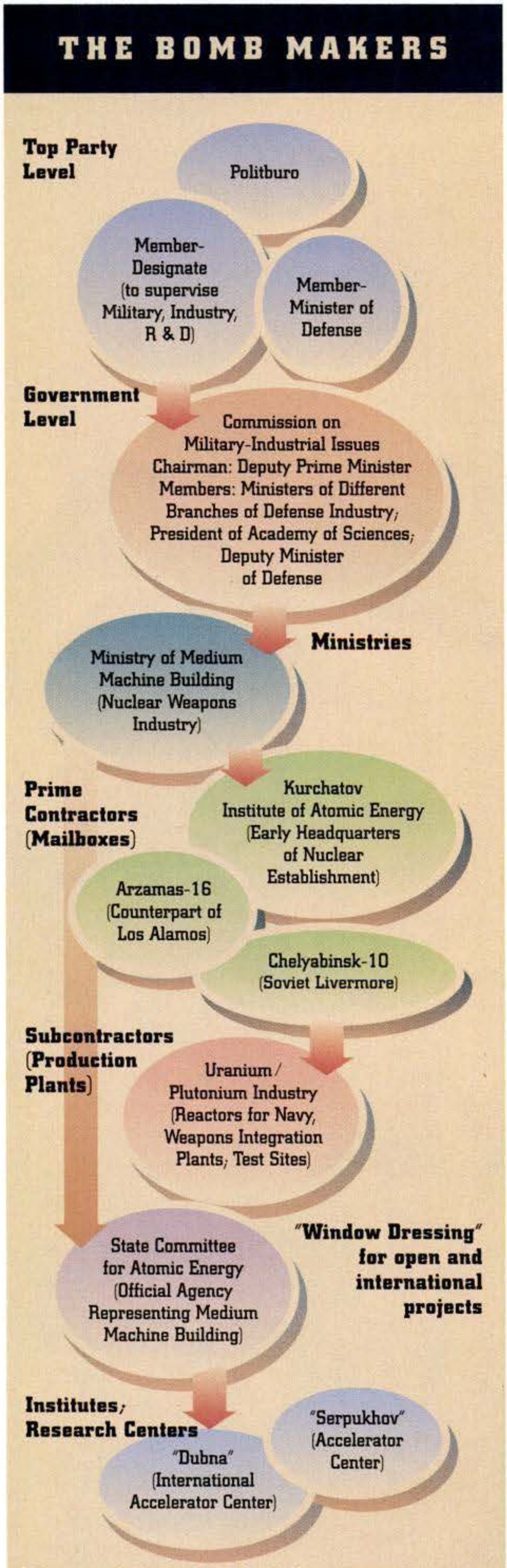
THE BOMB MAKERS
Top Party Level
Politburo
Member-Designate (to supervise Military, Industry, R & D)
Member-Minister of Defense
Government Level
Commission on Military-Industrial Issues
Chairman: Deputy Prime Minister
Members: Ministers of Different Branches of Defense Industry; President of Academy of Sciences; Deputy Minister of Defense
Ministries
Ministry of Medium Machine Building (Nuclear Weapons Industry)
Prime Contractors (Mailboxes)
Kurchatov Institute of Atomic Energy (Early Headquarters of Nuclear Establishment)
Arzamas-16 (Counterpart of Los Alamos)
Chelyabinsk-10 (Soviet Livermore)
Subcontractors (Production Plants)
Uranium / Plutonium Industry (Reactors for Navy, Weapons Integration Plants; Test Sites)
State Committee for Atomic Energy (Official Agency Representing Medium Machine Building)
"Window Dressing" for open and international projects
Institutes; Research Centers
"Dubna" (International Accelerator Center)
"Serpukhov" (Accelerator Center)

The organization of the Soviet bomb program was typical of the structure of the scientific establishment. Directing the program was the head of the KGB, Lavrenti Beria. "Medium Machine Building" is a code name for "nuclear." The Ministry of Rocketry was called "General Machine Building."

TOM WHITE

ence, not a member of the old intelligentsia, who were distrusted to the point of paranoia. Even prior to the war, Kurchatov proved himself to be a bright experimentalist in the newly developed field of nuclear physics. For Stalin, however, it was even more important that Kurchatov was considered a faithful communist. Among his scientific siblings, Igor Kurchatov acquired a reputation for great inner self-discipline and organization.

The very first installation built for Kurchatov was a "mailbox" under the cover name of the Laboratory of Measuring Instruments. (Mailboxes were names given to classified facilities to keep them secret.) In fact, this installation became the headquarters of the Soviet version of the Manhattan Project, bringing together the best of the nation's scientists.

Some crucial discoveries in nuclear physics had been made earlier in the Soviet Union. On the eve of the German surprise attack in June 1941, two young physicists, Yakov Zeldovich and Yuly Khariton, published, in an open scientific journal, a paper on the possibility of nuclear chain reactions in uranium. Another paper, on the spontaneous decay of uranium, was written by a young Ph.D., Georgi Flerov. In the winter of 1942, Flerov sent a letter from the trenches to "Comrade Stalin," literally begging him to start an atomic bomb building program.

Lieutenant Flerov was delivered to Moscow directly from the front line to participate in the new program. From everywhere, dozens of the best physicists and engineers were recruited and assigned to Kurchatov's installation. The participants in the nuclear bomb program were even given the right of "extraterritoriality." This was the highest form of privilege. It meant that the individuals so covered were not subject to harassment by local authorities. They reported directly to the highest levels of government.

Any resources requested by these "saviors" of the nation would be delivered as soon as possible, despite the hardships of the late stages of the war and the early postwar years. If suppliers or contractors did not move quickly enough, they faced Lavrenti Beria, who wore two hats—as supervisor of the bomb program and as head of the feared NKVD, predecessor of the KGB.

Kurchatov's installation was only the tip of a huge nuclear empire, named the Ministry of Medium Machine Building. It was comprised of hundreds of different nuclear enterprises, each performing specific tasks. And it was "Mailbox Moscow Center, 300" that was responsible for the ultimate bomb designs. That was the designation for the super-secret installation Arzamas-16, located about 400 kilometers east of Moscow. The closest city was the industrial center of Gorky, now Nizhny Novgorod. (Only recently was this mailbox officially named the All-Union Research Institute of Physics.)

This massive, concentrated effort brought the desired results. In 1947 Kurchatov, at his own installation in Moscow, achieved the first important breakthrough. His team put together the first Soviet nuclear reactor, which was modeled after the design of the first U.S. reactor. The American device, consisting of uranium oxide "eggs" surrounded by graphite blocks, was built by a team led by the physicist Enrico Fermi in a squash court at the University of Chicago. In 1942, this team generated the first self-sustaining nuclear chain reaction, kept going as neutrons emitted by fissioning uranium atoms split other atoms—a key step in developing the atomic bomb.

Kurchatov's success in building a nuclear reactor, together with other data, paved the way for final assembly of the first Soviet atomic bomb at Arzamas-16. It was designed by a team led by Yuly Khariton.

The decades-long U.S. nuclear weapons program has no counterpart to the role played by Yuly Khariton. This extraordinary physicist has been intimately connected with nuclear weapons research for more than 50 years, longer than any other scientist, East or West. At age 88, Khariton is still active in the work of Arzamas, with the title "Science Director Emeritus." (One present task at Arzamas is to ensure the ongoing safe dismantlement of nuclear weapons. Another is to make such weapons accident- and terrorist-proof. This pursuit

[Continued on page 74]

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WERE THEY SPIES?

An 87-year-old retired KGB general, Pavel Sudoplatov, who was the chief of atomic espionage in 1945-1946, has reopened the atomic-spies story in his just-published book, *Special Tasks: The Memoirs of an Unwanted Witness—A Soviet Spymaster*. Sudoplatov makes sensational charges against some of the greatest names in 20th century physics, including Niels Bohr, Enrico Fermi, Leo Szilard, and Robert Oppenheimer. He accuses these chief scientists of the Manhattan Project—all dead—of having turned over secret material on the bomb program to the Soviets.

These charges are, in fact, baseless, and were immediately refuted by the international scientific community, historians of science, members of the Manhattan Project who were witnesses to events at Los Alamos and elsewhere, and even the members of the Russian Intelligence Services themselves.

For example, the book says that Leo Szilard passed "vital information" from the Los Alamos bomb laboratory; however, Szilard never worked there.

The Russian Foreign Intelligence Service (the renamed KGB) issued a statement in May saying that Sudoplatov had exaggerated his role in atomic espionage and that his department had had no direct contact with any agents' network. "Allegations that Soviet intelligence received information on the atomic bomb directly from such noted scientists as Enrico Fermi, Leo Szilard, Robert Oppenheimer, and others do not correspond to reality."

One of the most incredible allegations is that the Danish physicist Niels Bohr, a Nobel laureate, was guilty of nuclear espionage for the Soviets. In 1945, when Bohr had returned to Denmark, Sudoplatov sent his envoy, Yakov Terletsky (under cover as a physicist), to Copenhagen—allegedly to consult with Bohr on a nuclear reactor. According to Sudoplatov, the Soviets were trying to assemble their own nuclear reactor with a stolen American recipe. He claims that during the attempt a serious accident occurred involving plutonium. As a result, the whole program had come to a halt, and the Soviets decided to send a delegation to seek Bohr's advice.

This reason given by Sudoplatov for the meeting with Bohr is absurd. The Russians could not have had plutonium at all before they had successfully activated a reactor, which did not happen until 1947.

The visit to Copenhagen did indeed take place, however. Under Lavrenti Beria's supervision, the leaders of the Soviet nuclear program quickly compiled a list of questions to be asked of Bohr. The Soviet Embassy in Denmark approached the physicist with a request to receive Soviet visitors. Bohr agreed, but immediately notified Danish authorities.

Sudoplatov tells us that Bohr answered the questions of his KGB interlocutor, easily explaining technical details on a sketch of a reactor.

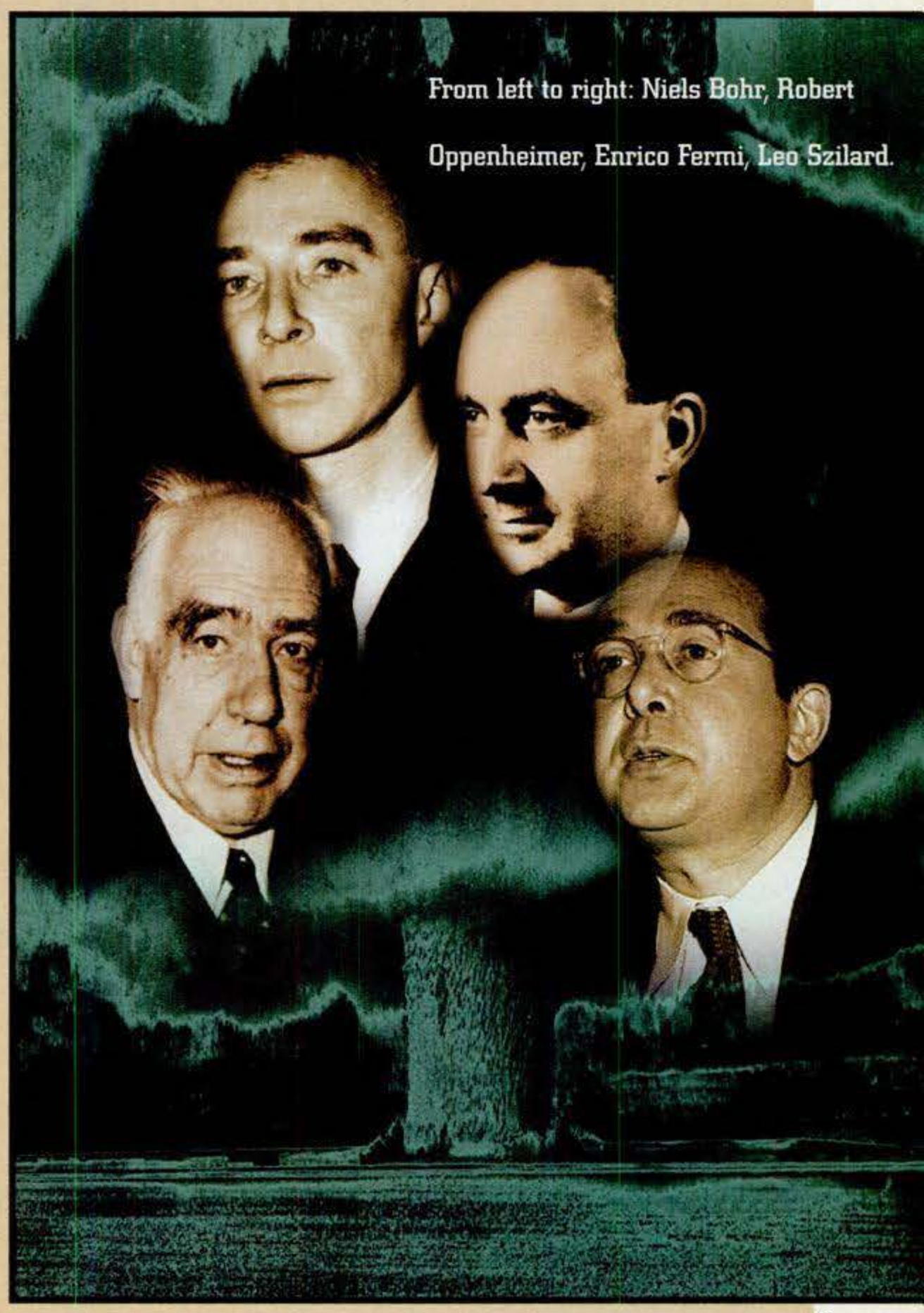
Amused by this portrait of the great theorist's ability to identify the smallest reactor engineering details, I asked Nobel laureate Hans Bethe, the head of theory in Los Alamos during the war, whether he could imagine such an exchange. "I knew much more about these problems than Bohr, but I would have been unable to do what is attributed to him," he told me.

The son of Niels Bohr, Aage (a physicist and also a Nobel laureate), was present at the meeting and says that no sketch or drawing was produced. Bohr did not discuss anything beyond science that had been published openly.

Yakov Terletsky, the KGB man sent by Sudoplatov, happened to be one of my professors at Moscow State University. In an account that became public after his death in 1993, he confessed that the Bohr meeting had been a complete failure. When asked specific technical questions related to nuclear issues, Bohr made only general remarks and modestly alluded to his incompetence in technical details. According to Terletsky, Bohr carefully observed the boundaries between open and classified science. In his account, Terletsky did not even mention an exchange regarding nuclear reactors, the principal reason alleged by Sudoplatov for the meeting. At the end of the meeting, Bohr apparently gave Terletsky a copy of the Smyth Report, an unclassified paper on the Manhattan Project, then recently published by the Atomic Energy Commission.

Subsequently, Beria reported to Stalin that Terletsky's mission had been a great success. Since Beria had been personally directing the visit to Copenhagen, it is not surprising that Beria pronounced the effort "a victory" and left records in the archives to support that contention.

Ironically, Western authorities may have filed a similar assessment. Bohr kept Terletsky waiting two weeks before he agreed to meet with him, enough time for Danish and British intelligence agencies to coach him on what precautions to take, and perhaps even bug the meeting. Knowing that Bohr had disclosed no secrets, perhaps they too declared a victory in as-yet-unopened intelligence files.—*R. S.*



From left to right: Niels Bohr, Robert Oppenheimer, Enrico Fermi, Leo Szilard.

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BY MARIETTE

COUNTERPOINT

Russian emigres to the United States have also made key contributions: Theodosius Dobzhansky advanced evolutionary genetics; Otto Struve explored stars' chemical makeup; Igor Sikorsky invented the helicopter; and Vladimir Zworykin's iconoscope was an early TV system.

THE GRANGER COLLECTION

1902
Drool On Cue

Ivan Petrovich Pavlov formulates the law of reinforcement; he demonstrates that a dog given food when a bell is rung will soon learn to salivate at the sound of the bell alone.

1799
Frozen In Time

A perfectly preserved 33,000-year-old woolly mammoth is found frozen in the Siberian Lena River Delta.

THE BETTMANN ARCHIVE

1975
Space Meeting

The first cooperative U.S.-Soviet space mission, the *Apollo-Soyuz* Test Project, is launched; a three-man *Apollo* spacecraft docks with the two-man Soviet *Soyuz 19*.

1742
Christian Goldbach suggests that every even number greater than two is the sum of two primes. Though verified for all natural numbers up to 100 million, Goldbach's conjecture has defied all attempts at proof or disproof.

1748
Mikhail Vasilievich Lomonosov formulates the laws of conservation of mass and energy, fundamental tenets of natural science.

1829
Nikolai Ivanovich Lobachevsky publishes his version of non-Euclidean, hyperbolic geometry. The new geometry makes possible the radical notion that the universe may be curved rather than flat.

1844
Chemist Carl Carlovich Claus is first to obtain pure ruthenium (from the medieval Latin *Ruthenia*, or *Russia*).

1861
Beginning a new era in astronomy, Russian-German physicist Gustav Robert Kirchhoff's map of the solar spectrum shows that elements can be detected in the sun's atmosphere by means of dark lines they cause.

1869
Dmitri Ivanovich Mendeleyev publishes his periodic table, which organizes all known chemical elements by their atomic weights. The foundation of modern chemistry, this table forms the basis for understanding elemental interrelationships.

1870s
After exploring central Asia, Nikolai Mikhaylovich Przhevalsky returns with many previously unknown species; the most famous is Przhevalsky's horse, the last truly wild breed.

1884
Russian-French bacteriologist Ilya Illich Mechnikov discovers phagocytes, amoeba-like white blood cells that devour organisms invading the body.

1892
Studying the mosaic disease of tobacco plants, microbiologist and botanist Dmitri Iosifovich Ivanovsky deduces the existence of viruses, organisms too small to be seen in the microscope.

1895
Physicist Konstantin Eduardovich Tsiolkovsky, among the first to work out the theoretical problems of rocket travel in space, proposes liquid fuel for propulsion.

1897
Acclaimed in Russia as the inventor of the radio, physicist and electrical engineer Alexander Popov creates the first modern antenna to transmit radio waves wirelessly.

1898
The Russian-designed *Ermak* is the first icebreaker. It becomes a successful prototype for many other ships.

1901
Introducing the first practical application of a technique developed in 1785, biologist Ilya Ivanovich Ivanov founds a center for artificially inseminating cattle.

1901
Peter Nicolaievich Lebedev measures the radiation pressure of light, confirming Maxwell's theory of electromagnetism and setting the stage for a modern understanding of the phenomenon.

1907
Mathematician Andrei Andreyevich Markov develops the theory of linked probabilities, called Markov chains, in which the probability of one event affects that of the next.

1922
On the basis of Albert Einstein's general theory of relativity, Alexander Friedmann predicts that the universe must be expanding.

1934
Biologist G. F. Gause is the first to state that two similar species cannot long occupy similar ecological niches. Gause's principle becomes

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YEARS of Russian Science & Technology

DiCHRISTINA

SOVFOTO / EASTFOTO

1968
Supersonic Plane

The Tupolev-144 ushers in supersonic passenger travel with its maiden flight, two months before the Concorde.

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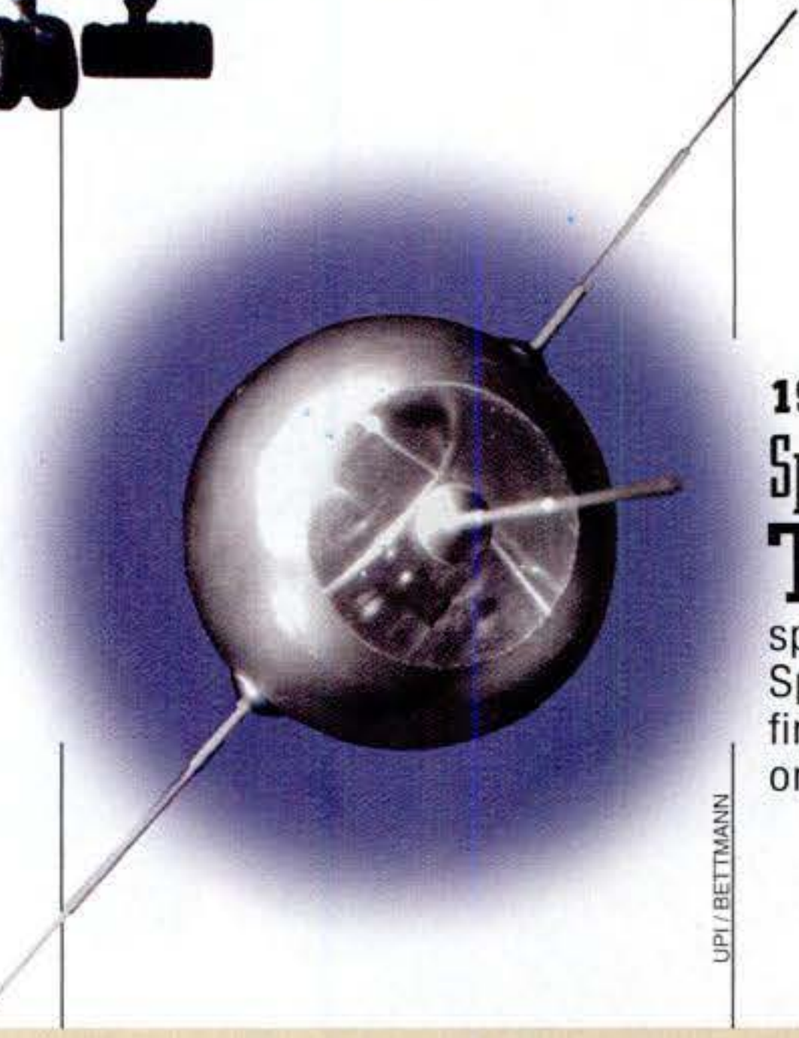
1991
Return To *Titanic*

Twin Russian MIR submersibles, the most powerful of their class in the world, descended two miles into the North Atlantic in a Canadian-American-Russian mission to search for new clues to the cause of the *Titanic*'s sinking.



UPI / BETTMANN

1957
Sputnik

The kickoff of the great space race: Sputnik is the first Earth orbiter.

a key to understanding species interrelationships.

1934
Pavel Alexeyevich Cherenkov discovers that a particle traveling close to the speed of light emits light when it passes through a liquid or a transparent solid. This principle is used extensively in high-energy physics to detect charged particles and measure their velocities.

1935
Theoretical physicist Lev Davidovich Landau clarifies the understanding of ferromagnetism when he publishes a mathematical explanation of the behavior of atomic magnets.

1936
In his book *The Origin of Life on Earth*, biochemist Alexander Ivanovich Oparin offers the idea that life evolved from random chemical processes in the ocean, which became a biochemical "soup" conducive to early life forms.

1937
Physicist Peter Leonidovich Kapitza discovers that helium II (the stable form of helium below 2.2°K) is a superfluid —it has almost no viscosity, or resistance to flow.

1941
The Maksutov telescope, in which aberration is corrected by a spherical meniscus, is invented in Moscow.

1947
Astronomer Victor Amazaspovich Ambartsumian discovers that new stars are still forming in the Milky Way galaxy.

1950s
The Tokamak device for nuclear fusion is invented. Although it has not achieved sustained fusion, it is still considered among the most promising designs.

1954
The Soviet Union builds the first nuclear reactor for power generation. It is capable of producing 5,000 kilowatts.

1957
The *Lenin*, the first atomic-powered surface ship and the world's largest icebreaker, is launched.

1958
Russia sends the first dog into space. The pooch, Laika, remains alive for 10 days, proving that animals can survive in space.

1959
Space probe Lunik II provides the first images of the far side of the moon.

1961
In his 1.8-hour mission aboard *Vostok 1*, cosmonaut Yuri Gagarin becomes the first human to orbit Earth.

1963
For the first time, two spacecraft with humans aboard (Andrian Nikolayev and Pavel Romanovich Popovich) orbit Earth simultaneously.

1964
Soviet physicists Nikolay Gennadiyevich Basov and Alexander Mikhaylovich Prokhorov share the Nobel Prize for Physics with Charles Townes of the United States for the development of maser and laser principles in quantum mechanics.

1965
Alexei A. Leonov takes the first space walk, a 20-minute excursion outside *Voskhod 2*.

1975
Venera 9 and Venera 10 provide the first pictures from the surface of Venus.

1984
Exploring Earth's inner space: In the Kola Hole, Soviet researchers drill to a depth of 12 kilometers (7.5 miles) and reach Earth's lower crust.

1987
Cosmonaut Yuri Viktorovich Romanenko sets a new record when he returns to Earth from the *Mir* space station after 326 days.

1987
The revolutionary transport aircraft WIG, or Ekranoplane, operates on the principle of displacement on a cushion of air.

1994
Cosmonaut Sergei Krikalev is the first Russian to fly on the American space shuttle, paving the way for future cooperative space ventures.

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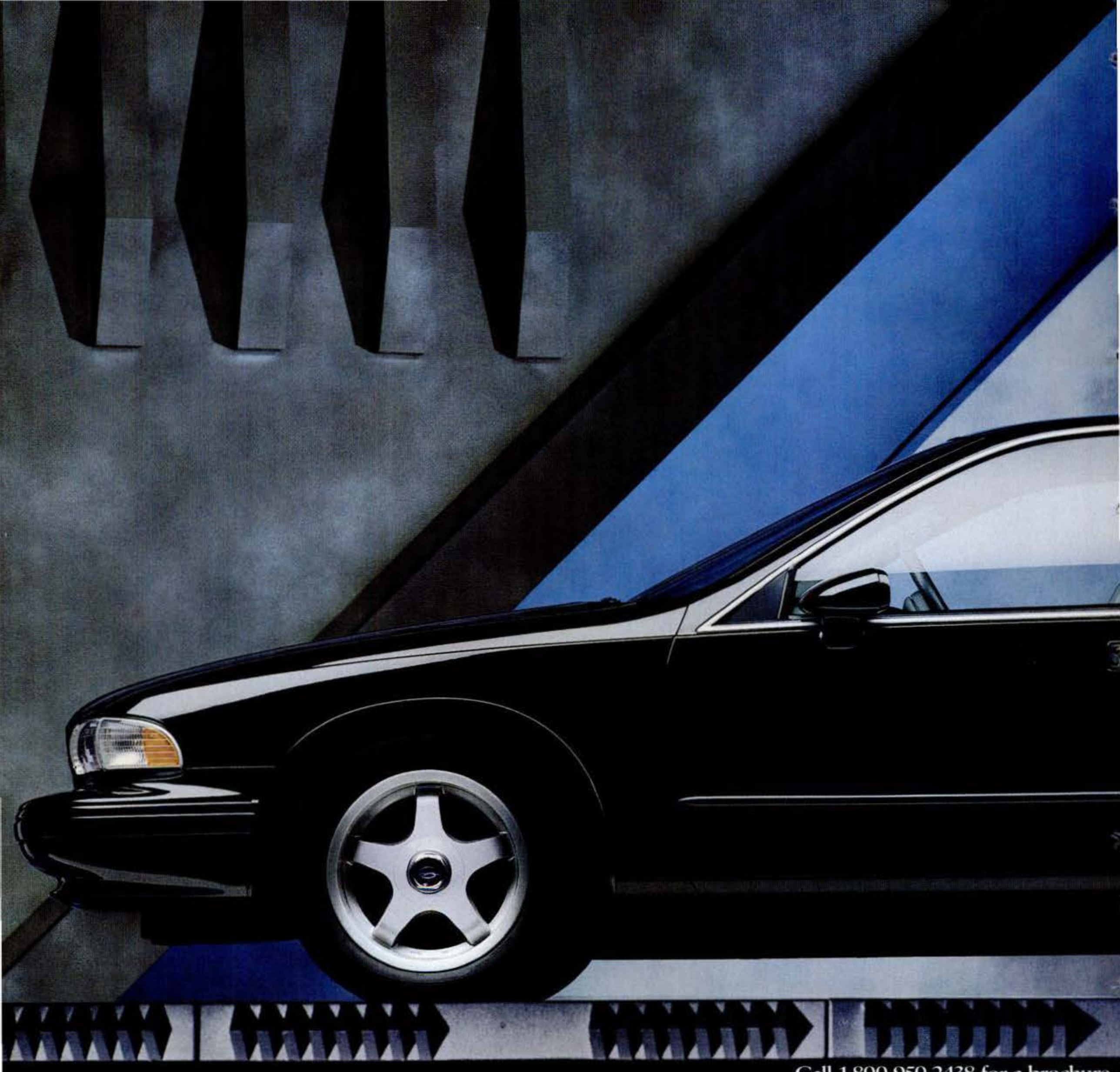

So much for arriving

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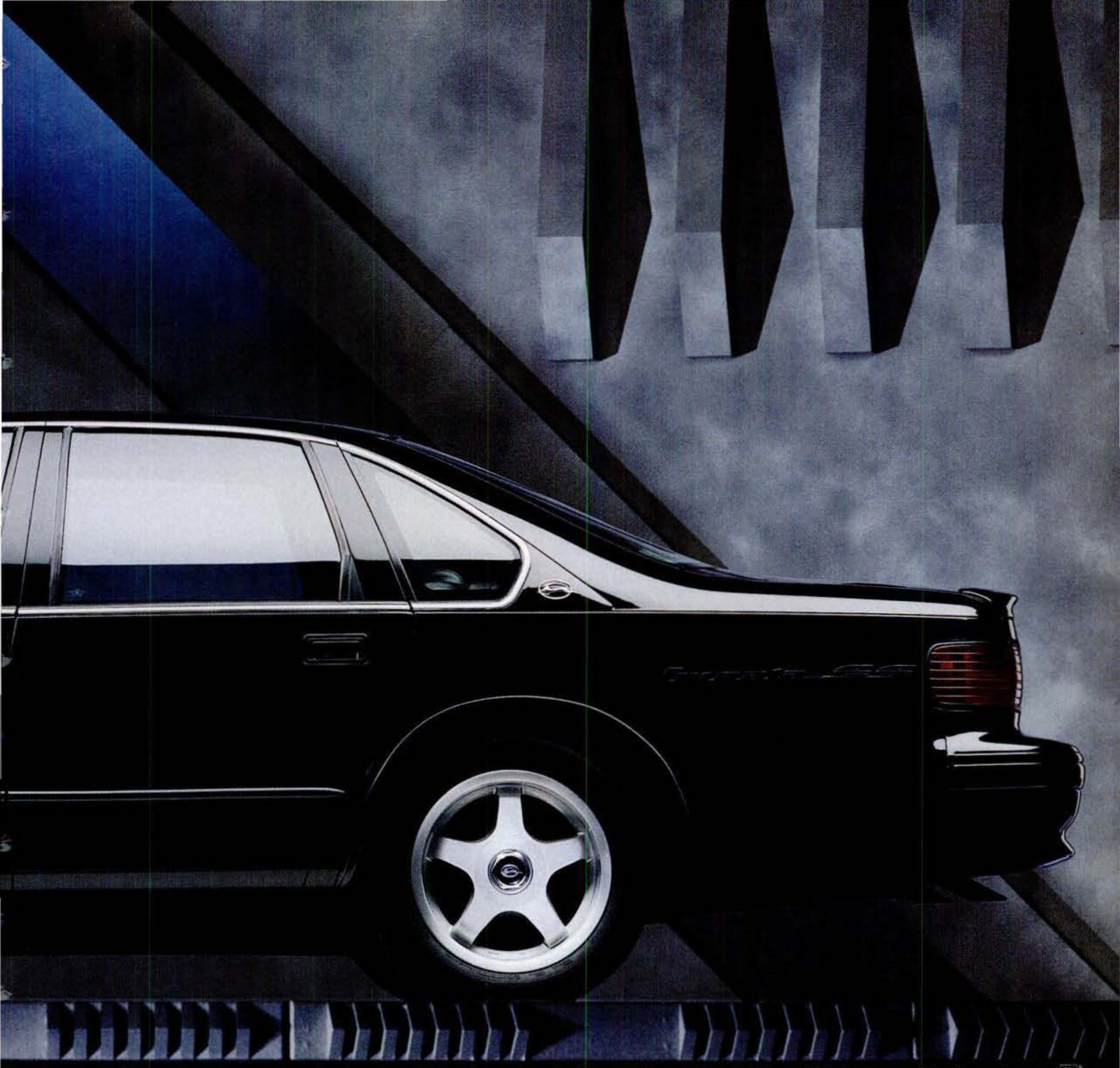

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COUNTERPOINT

In the United States, the Clean Air Act, the Clean Water Act, and the Comprehensive Environmental Response Compensation and Liability Act (commonly known as Superfund) have helped limit environmental damage.

The 1980 Superfund law was passed following the discovery of hazardous wastes at Love Canal and other abandoned dumps. More than 1,200 dangerous sites have since been placed on a priorities list for cleanup. Over $15 billion has been spent on Superfund, but fewer than 200 cleanups have been completed.

Siberia at the Crossroads

Russia's vast landscape has reached an environmental boiling point, as the heedless plundering of its resources continues unchecked.

BY FRED PEARCE

"Let the fragile green breast of Siberia be dressed in the cement armor of cities, armed with the stone muzzles of factory chimneys, and girded with the iron belts of railroads. Let the taiga be burned and felled; let the steppes be trampled." So Vladimir Zazubrin, one of Josef Stalin's favorite writers, urged in 1926, after the Russian Revolution. "Only in cement and iron," he declaimed, "can the fraternal union of all peoples, the iron brotherhood of man, be forged."

Almost 70 years later, after the collapse of communism's "iron brotherhood," Russian scientists survey Stalin's legacy. From Chernobyl to the deforested Chinese border, from the rusting nuclear submarines in the Arctic Ocean to the salt-encrusted wastelands of what was once the Aral Sea, the cesspits of the former Soviet Union lie everywhere.

The Russian environment, like Russian society itself, is at a dangerous crossroads, says biologist Sviatoslav Zabelin, a former top official in Boris Yeltsin's administration and now chairman of Russia's largest environmental organization, the Socio-Ecological Union. The brutal and regimented ecological destruction of the past has ended. But it has been replaced by an equally damaging chaos, Zabelin says. "Nobody knows the rules of the game. There are honest people in the administration, people who want to protect the motherland. But it is not their time."

To understand the scale of what Stalin and his heirs did to the largest country in the world—a country where the sun rises in the east before it has set in the west—I traveled to its center. Halfway between the Polish border and Vladivostok on the shores of the Pacific, halfway between Afghanistan and the North Pole, is the Siberian city of Noyabr'sk. Only 12 years old, this city is not on many maps. But Noyabr'sk has a population of 100,000 and is a hub of one of

FRED PEARCE / STILL PICTURES

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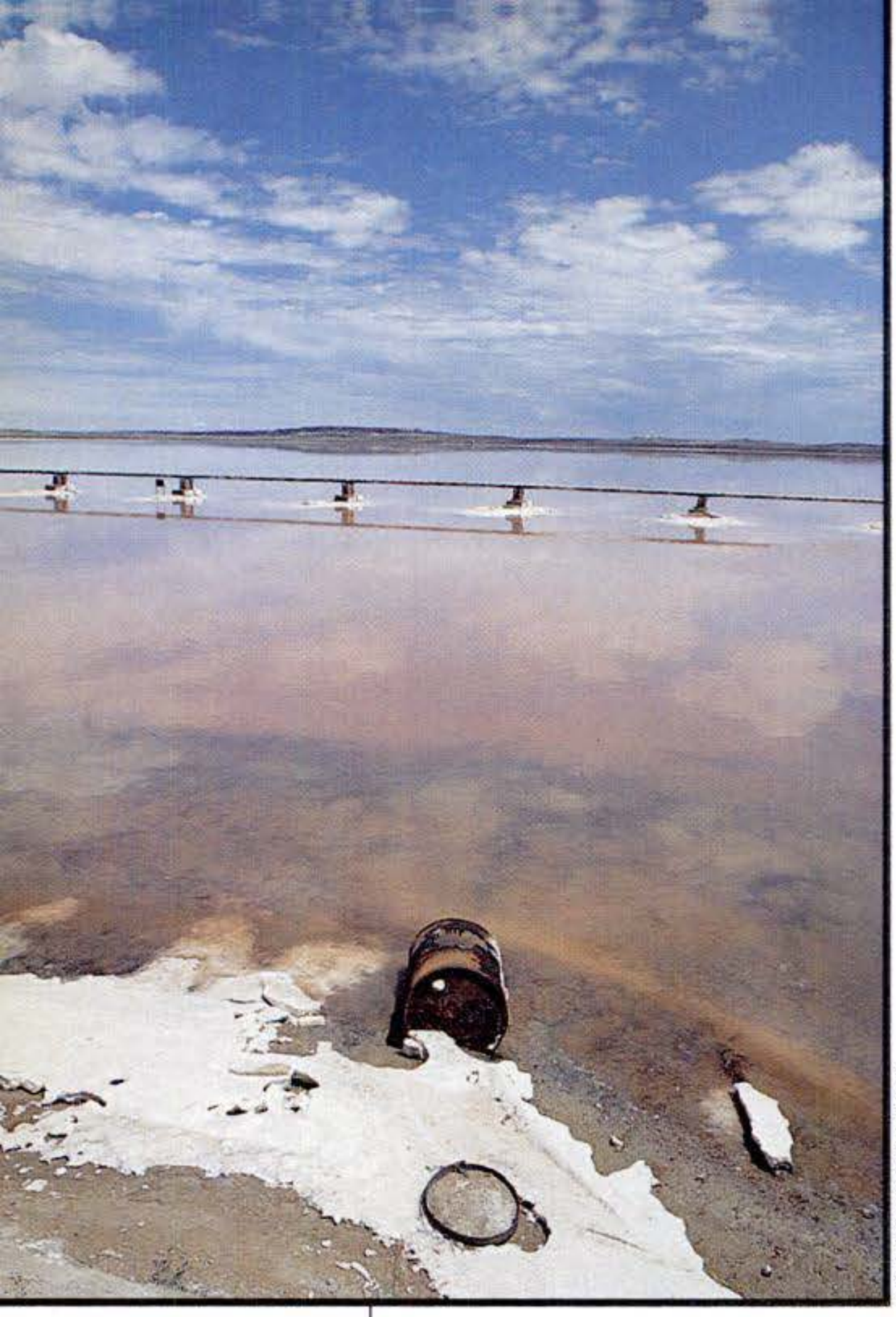

VICTOR GRITSYUK / MATRIX

Pollution from a chemical plant has destroyed this area of Turkmenistan.

burning fossil fuels. The burning and rotting of timber will unleash more carbon dioxide into the air.

Can the Siberian forests be saved? Forest reserves have a pedigree stretching back to Peter the Great, who created them to protect the fur-bearing sable. The Soviet rulers created more reserves. And last year, with assistance from the World Wildlife Fund in the United States, Russia created the Great Arctic Zapovednik, a nature reserve covering 42,000 square kilometers (roughly the size of Louisiana) on the Taymyr Peninsula of Siberia's northern coast.

Forestry and petrochemicals are not the only threats to Siberia. Reservoirs behind giant hydroelectric dams, many built to power metal smelting works, have flooded 100,000 square kilometers of forests in the valleys of the Yenisei and the Angara rivers in the past decade alone. The region has four of the ten biggest hydroelectric power plants on earth.

Polluted air from copper and nickel smelters in the far north hangs in the cold Siberian air through the long winters. The Petshenganikel smelter in Norilsk alone emits 280,000 metric tons of sulfur dioxide annually—more than Norway, Sweden, and Finland combined. More than 5,000 square kilometers of forests have died from the polluted air. Acid hazes spread out across the Arctic and into northern Canada.

Air pollution throughout the industrialized parts of the former Soviet Union represents a health hazard of a kind not seen in the West for a generation. According to the 1992 book *Ecocide in the USSR*, an estimated 70 million Russian people live in cities where the air pollution is five times worse than official limits. It partly explains why the country's population is now falling. According to recent data, the average age at death among Russian men is 59 years, compared with 72 years for white males in the United States.

The frightening thing, says Zabelin of the Socio-Ecological Union, is that "because of the secrecy, very often the officials don't have the information" about what pollutants have been released. Two years ago, after a detailed investigation, Zabelin's government colleagues in Moscow announced the discovery at military installations of seven storage tanks containing 40,000 metric tons of chemical weapons, more than enough to kill the entire population of Russia.

But that 40,000 metric tons, says Zabelin, is just the tip of a deadly iceberg. "During the period of production," he told me, "they made 400,000 metric tons. So where are they?" Some of the chemicals were poured into the Baltic Sea, he says, but "it may be, as with radioactive waste, that we will find many places polluted with chemical weapons."

Radioactive waste could prove one of the most lethal and long-lasting legacies of the Soviet era (see "Nuclear Chaos," this issue). Many radioactive materials have entered the environment as a result of accidents like the 1986 Chernobyl explosion. Other nuclear wastes have been intentionally dumped into oceans, lakes, and rivers.

Much of Russia's pollution has simply ended up in the sea. The almost-enclosed Baltic and Black Seas are today among the filthiest on earth—heavily contaminated with military, industrial, municipal, and farming wastes. The military has dumped uranium, thorium, mustard gas, and other chemical weapons and nuclear wastes into the Baltic. The Black Sea, a traditional holiday resort for Russia's elite, has "suffered catastrophic ecological damage," according to Laurence Mee, head of the International Atomic Energy Agency's marine laboratory in Monaco.

Pollution, much of it from the former Soviet Union, has caused a huge explosion in the Black Sea's populations of algae and jellyfish, which have now consumed most of the oxygen. The sea is "the largest anoxic water mass on our planet," says Mee. About 90 percent of its water, everything except the top layer, is devoid of oxygen.

The fate of Lake Baikal is endlessly discussed by Russian scientists. The lake is the largest body of fresh water in the world and has a unique and extremely fragile ecosystem. Thousands of forested acres around the lake have been cleared for cultivation, and paper and pulp mills discharge pollution into its waters.

Environmentalists from Russia and the United States have formed a partnership to draw up land-use plans for the entire Baikal area. And the U.S. State Department has allocated $450,000 a year to help the newly created Baikal Commission enact land-use restrictions. But so far, says Zabelin, "nothing has happened."

The most graphic symbol of the ecological bankruptcy of the old regime is visible from the commercial airline flights that now cross over the Aral Sea in former Soviet Central Asia en route to the far east. On moonlit nights, you can look down upon what was once the fourth largest inland sea in the world. You can pick out the lights of Aralsk, shown on maps as a port on the sea's northern shore. But instead of waves crashing into the town's harbor, the moon reveals a glinting white desert.

The Aral Sea's shoreline has retreated 60 kilometers in the past 40 years, as irrigation engineers have diverted about 40 cubic kilometers of water a year from the rivers that feed the sea. It was part of Stalin's grand plan to turn the region into the Soviet

[*Continued on page 73*]

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ALEXIS DUCLOS / GAMMA LIAISON

So bad are the fumes from the Selenguinsk paper pulp mill that workers there must wear masks. The mill discharges wastes into a river that feeds Lake Baikal, once pristine. It holds 20 percent of the world's supply of fresh water.

Russia's main resources is timber," and it would be "naive" to believe the country would not exploit its forests. Russian officials, particularly local administrators battling with Moscow for control of their resources, are now keen to begin cutting and are inviting Western companies to help them.

In the Russian Far East, the South Korean trading company Hyundai is clear-cutting the broadleaf and conifer forests of the Sikhote Alin mountains of Primorsky, one of the few remaining refuges for the last 300 or so Siberian tigers. Hyundai plans to triple its output, felling 4,000 square kilometers of forest each year. Meanwhile, the largest trader in Asian tropical timber, the Japanese firm C. Itoh, is logging the forests of Khabarovsk; and the U.S. firm Weyerhaeuser is interested in an area around the Botcha River. The proximity of these forests to Asian markets makes them appealing. But because the land is being privatized and reallocated, Weyerhaeuser's plans are currently on hold.

To reach the timber, the foreigners are building their own roads. Large areas of forest have also been opened up by the Baikal-Amur Mainline, a second Trans-Siberian railway through the heart of the timber region, begun under Stalin and finally finished under Gorbachev.

Rapacious foresters are not new to Siberia. One state timber enterprise, the Ust-Ilimsk Combine, established in the 1970s near the route of the Baikal-Amur railway, has its own new town, airport, and a hydroelectric power plant that flooded 2,000 square kilometers of forest. The combine was assigned an area of forest the size of Switzerland, where it set about removing every tree, leaving behind eroded hillsides and boggy valleys.

Russian forestry, like most of the nation's other industries, is immensely wasteful. Somewhere between 50 and 70 percent of the cut timber is lost or discarded. Forest fires, most started by humans or their machinery, claim more than 10,000 square kilometers of Siberian forest each year, and disease and insects take a similar toll. The hope for the future is that foreign methods will reduce the waste. The fear is that foreign markets will merely increase the rewards for pillaging the forests.

Anatoly Shvidenko, a leading forestry administrator in Moscow under Gorbachev, estimates that Siberia lost 20 percent of its trees between 1966 and 1988. Shvidenko believes that many of the largest forest regions could vanish altogether within 40 to 50 years. Forest recovery rates, he warns, are much slower in Siberia than in fast-growing tropical forests. Bounding through a forest outside Noyabr'sk, Shvidenko takes his axe to a small spruce tree, four meters high and as thick as his arm. In the tropics, such a tree might be 10 years old. Shvidenko counts the rings. "Look," he says, "this was a seedling a hundred years ago, when Tolstoy was still writing."

Siberian forests do not contain the teeming, noisy masses of life found in a tropical rainforest. They are silent and bare. Shivdenko says they probably contain, in total, fewer species of plants and animals than a single hectare in the Amazon. But their loss would damage world climate as much as the loss of tropical forests. Siberia's trees contain an estimated 40 billion metric tons of carbon—seven times the annual global output of carbon dioxide pollution from

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the world's most productive regions of oil and gas extraction.

Here, in Siberia, Russia's environmental problems are coming to a head. The oil men are working in what was, until they arrived, a pristine environment. Stretched hundreds of kilometers across the western Siberian plain is one of the largest regions of lakes and marshes on earth. The oil industry's assault, as I saw in many hours of helicopter flights, is turning this region into a blighted landscape of almost unimaginable proportions.

The area is covered with a network of endless roads, laid through forests or on wide embankments across lakes and bogs; pylons; oil pipelines; drill rigs; and narrow gashes that mark the lines of old seismic surveys. All pollute the lakes and bogs, and divide them into thousands of fragments, each at most a few hundred yards across.

Clouds of black smoke spread to the horizon from burning pools of waste oil. Small patches of desert form around sand quarries, and dunes rise in the wind. Many forests are charred. Millions more trees lie broken, cut down to make way for the roads and pipes. The Siberian forests and bogs are littered with abandoned high-tension cables, rusting pipes, and broken machinery. There are few signs of wildlife. The reindeer are long gone; even the birds have departed.

Vladimir Sedykh, director of Siberian forests at the Russian Academy of Sciences, claims that since the 1960s, the Siberian oil and gas industry has caused "the destruction of the environment in western Siberia on a scale and at an intensity having no equal in the world."

Western oil experts on our expedition look askance. "The place is just a mess," says Bob Turnbull, a Scottish engineer accompanying me on the visit. "The big problem is that their technologies are 40 years out of date. Modern methods could replace 20 or more well pads with a single drilling point." The difference would be profound. The region around Noyabr'sk alone has 12,000 oil wells, according to Guennady Khramov, chief engineer of the local oil company, Noyabr'skneftegas. Each well produces about 40 million metric tons of polluted water a year and has its own road, pipes, power lines, and waste lagoons.

Outdated technology also ensures that much of the gas and oil produced here is wasted. Western estimates put the loss of oil from pipeline leaks at 10 percent. From space, some of the brightest lights on the planet are from the flaring of unwanted natural gas at thousands of oil wells in western Siberia.

Fly north of Noyabr'sk, and you eventually reach virgin swampland. Past an abandoned Stalin labor camp, called Gulag 501 Construction Enterprise, is the tiny hunting and fishing town of Krasnoselkup on the banks of the Taz River, one of the great Siberian rivers that flow into the Arctic Ocean. Engineers are just starting to drill for oil here. The main test rig is 100 yards from Devil's Lake on the Tolka River, a tributary of the Taz. The lake is a major local center for wildlife. I saw hundreds of swans and reindeer, and the occasional brown bear bounding through the swamp. But for how much longer? The deputy mayor of the town of Krasnoselkup, Alexander Naletov, says the drilling is frightening the reindeer away from their pastures and poisoning fish spawning grounds.

If the reindeer retreat, so must such indigenous tribes as the Selkup. One Selkup family, camping beside the river, told me the story of their centuries-long northward march to ever-harder lands in the face of advancing Russians. Since the end of communist rule, they have been allowed to venerate their shaman and his sledge-load of sacred objects. But little else has changed.

Northern Siberia is a world so cold that in places the soil and rock are frozen as deep as a kilometer. The region is so vast that forest fires can burn for months, unnoticed except by satellites. Siberia's dark, closed forests of pine, fir, spruce, and larch contain a fifth of the planet's trees. They cover six million square kilometers, twice the area of the Amazon rainforest.

Delegates attending the 1992 Earth Summit in Rio de Janeiro agreed that the great northern forests deserve as much protection as tropical rainforests. But V.I. Danilov-Danilian, who was then Russian minister for the environment and natural resources, warned that "one of

Irrigation diversions have reduced the Aral Sea to one-third its original size, stranding fishing boats (below). The dry seabed is polluted with pesticides and salt deposits (right).

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Spilled oil

contaminates a

lagoon near the

Siberian city of

Noyabr'sk

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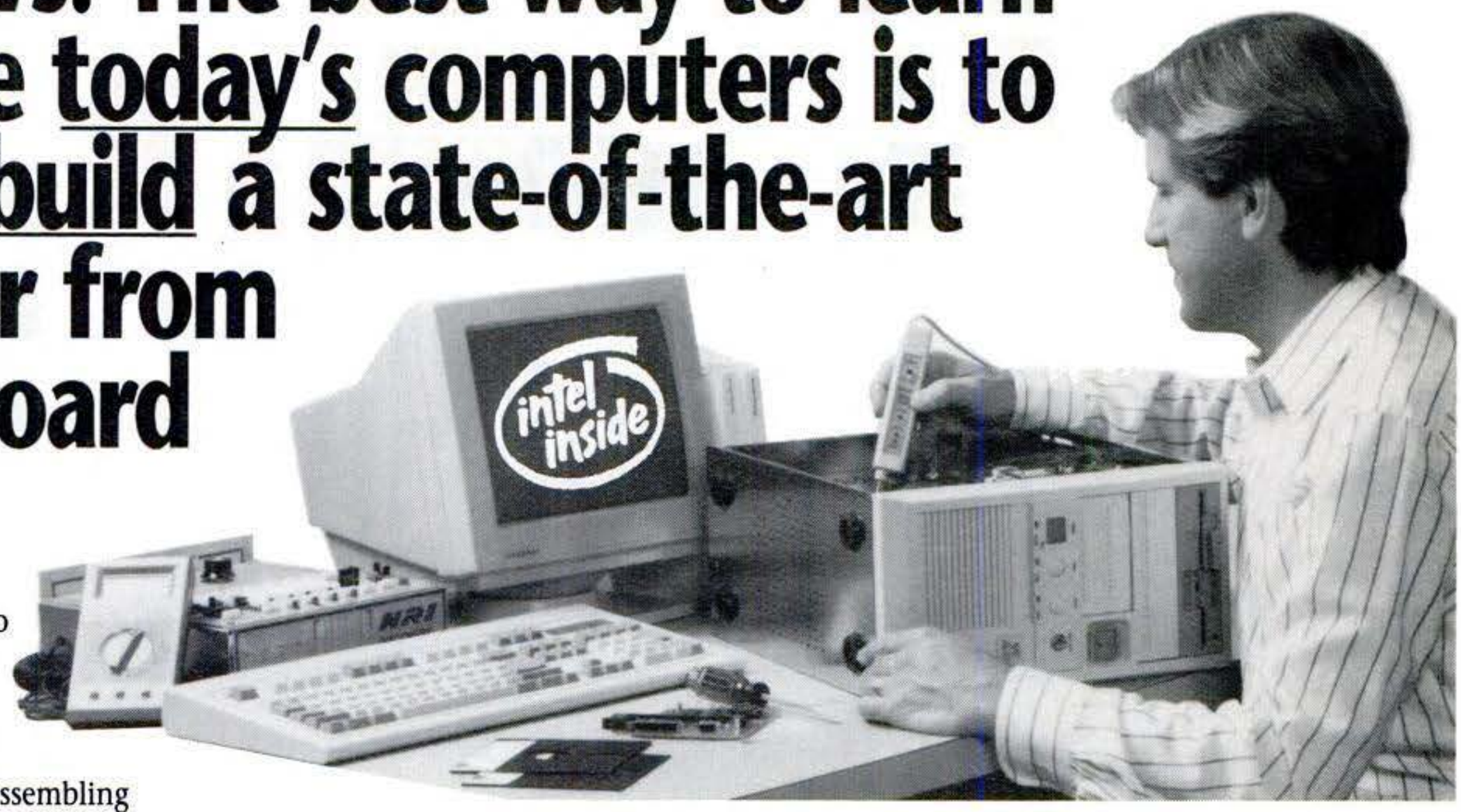

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- QBasic
- Microsoft Works
- Ultra-X diagnostic package

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COUNTERPOINT

The average family income in the United States is about $2,600 a month; in Russia it's $30 a month. Thus the gap between American and Russian standards of living is huge. Witness the percentage of U.S. households with: Color TVs; 97% • Cars; 91% • VCRs; 91% • Clothes washers; 86% • Microwave ovens; 83% • Clothes dryers; 81% • Answering machines; 57% • Dishwashers; 54% • Cordless phones; 49% • CD players; 43% • Personal computers; 37% • Cellular phones; 10%

Lifestyles *of the* Not-So-Rich

BY LEONID ZAGALSKY

A well-known Russian joke proclaims: "There are too many people in this country and too few things. The only way out of this situation is to have fewer people."

Most Russians in Soviet times had no hope that the country would ever produce enough of the things that make life easier. Even now, in the new era, that has not changed. Russian appliances—televisions, VCRs, CD-players, even your basic washers, dryers, and refrigerators—are still a joke.

One of the great paradoxes is that in a country with a huge nuclear arsenal, arguably the best jet fighters, and the biggest fleet of spaceships and satellites, it is still next to impossible to go into a department store and buy a Russian-made food mixer, coffee maker, or even that kitchen necessity in a society where all meat comes in chunks and slabs—a meat grinder.

Yet, thanks to the ever-ready Japanese, Taiwanese, and Korean manufacturers, microwave ovens, VCRs, and brand-new TV sets are gradually finding their way into Russian apartments.

And if you see six Russians sitting in a restaurant with six cellular telephones and six beepers lying on the table, do not be alarmed. These are not drug dealers. They are the new Russian businessmen. Life in Russia has become a crazy mixture of creaky, outdated technology and the latest fads; there is a growing demand for the normal conveniences of life and a lingering suspicion of all things new and foreign. That's why in Izmailovo, the biggest flea market in Moscow, a tourist with a sense of humor can buy a huge wooden abacus inscribed with the words "Russian computer."

Most stores in Russia now have calculators at the cashiers' desks. But Russian cashiers, especially the older ones, have a tendency to add up the purchases first with the calculator, then with an abacus just to make sure.

Personal computers were alien objects until the end of the 1980s, when Mikhail Gorbachev passed a decree ordering "total computerization of the country." Every high school in the country was required to create "computer classes," where the kids could learn how to operate PCs.

Of course, the computers came from abroad. Russian PCs, as people joked, were only good for cracking nuts.

Most people today just don't have enough money for computers. In the last couple of years, though, some individuals have started buying PCs. Some are successful writers who can afford to spend $1,500—the equivalent of two years' salary for the average Russian. Others are the rapidly growing class of young wheeler-dealers, who prefer laptops. They are mostly for show; I doubt that these young guys know how to get much use out of them.

Computer games are available in Russia, and like the American movies available everywhere on videocassettes (sometimes before they are available in the United States), they are mostly pirated.

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The idea of having modern, world-class goods and services is a sad joke for most Russians.

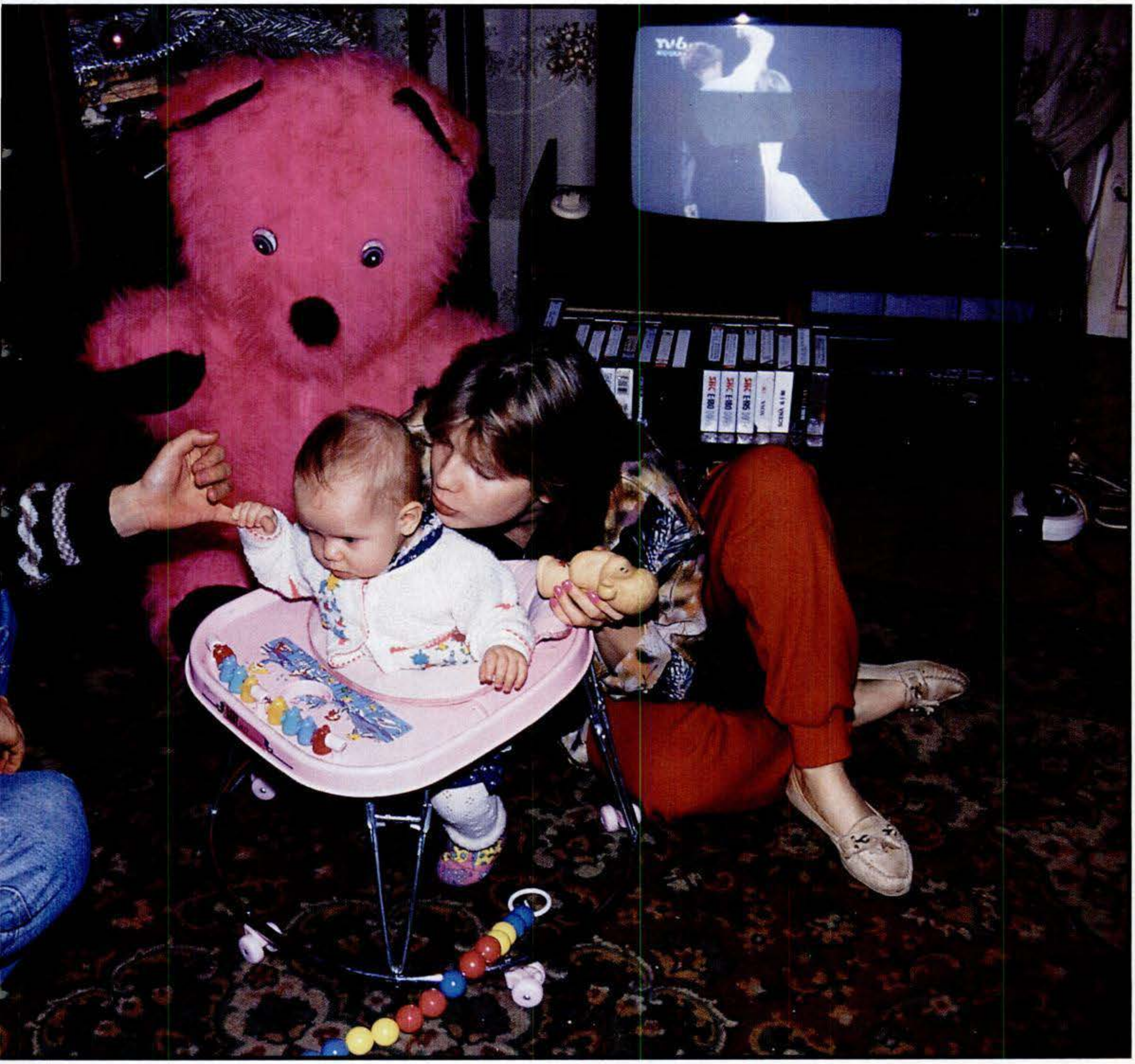
Russia has signed the convention prohibiting the unlicensed production of movie videos, but it is not enforced. No one even talks about pirated games. So computer games are available at almost every street kiosk, and you can be sure software companies are not receiving royalties for them.

It is possible to buy Game Boy, Super Nintendo, or Sega at a few places in Moscow. (I doubt that kids in rural areas know what these words mean.) But the price is so high that only a very rich family can afford to spoil their children with such stuff.

Russia has about 12 phone lines per hundred people. Compare this with 56 lines per hundred people in the United States. Some Russians have been waiting for more than 30 years to receive a telephone line. Some who are now pensioners will die before they get a telephone in their own apartment.

Using a telephone in Russia is torture. Most are rotary; there is no touch-tone system. Connections are often interrupted by static, and you never know whether you will actually get the number you have dialed. Options like call-waiting, call-forwarding, and conference calling do not exist. There is no directory assistance—and there are no

Center of Russian family life, the TV, or "blue box," is given a place of honor in the "red corner."



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NIKOLAI IGNATIEV / MATRIX

Home electronic equipment is available, but it comes from abroad, like these Japanese boom boxes.

published telephone directories.

Public telephones are a nightmare. The few that work require coins, of course—there is no such thing as a collect call, let alone a calling card. The cost of a local call is only a ruble, less than a tenth of a cent. But the coins have all but disappeared from the marketplace in the last few years because of skyrocketing inflation. Some enterprising newsstand vendors have made small fortunes by selling one-ruble coins for three to five rubles.

Only the biggest cheeses have secretaries who can at least take messages if their bosses are on the phone. Otherwise, you dial repeatedly when you get a busy signal until the party you are calling has finished talking. Bear in mind that Russians love to talk on the phone and can do this for hours. A nice gift for a Russian friend might be a foreign-made phone with an automatic redial feature.

Or how about an answering machine? These are not widely used, though, and some people get upset or even frightened if their call is answered by an electronic voice. Some of my friends have felt insulted by my answering machine. One told me, "I did not deserve that. I want you live." Of course, he had refused to leave a message.

Beepers are status symbols, and carrying a cellular phone is a matter of particular pride. Russians who own them love to show off by constantly talking on them everywhere they go. If you know what's what in Moscow, you will reach only one conclusion when you see someone talking on a cellular phone: This guy is doing really well.

Electronic toys and status symbols are one thing; the daily necessities of life are another. Most Russians still can afford neither. But you would think it is high time for this great industrial power to produce appliances that work and that its citizens can afford to buy.

Dishwashers, microwave ovens, and washers and dryers are luxuries, and the majority of Russia's 145 million people have no idea what these wonderful things are for. Try to explain to a Russian housewife the term "garbage disposal"—and the notion of grinding organic waste directly inside the kitchen sink! On a recent trip to Russia, I did not even see any Russian-made irons in the stores.

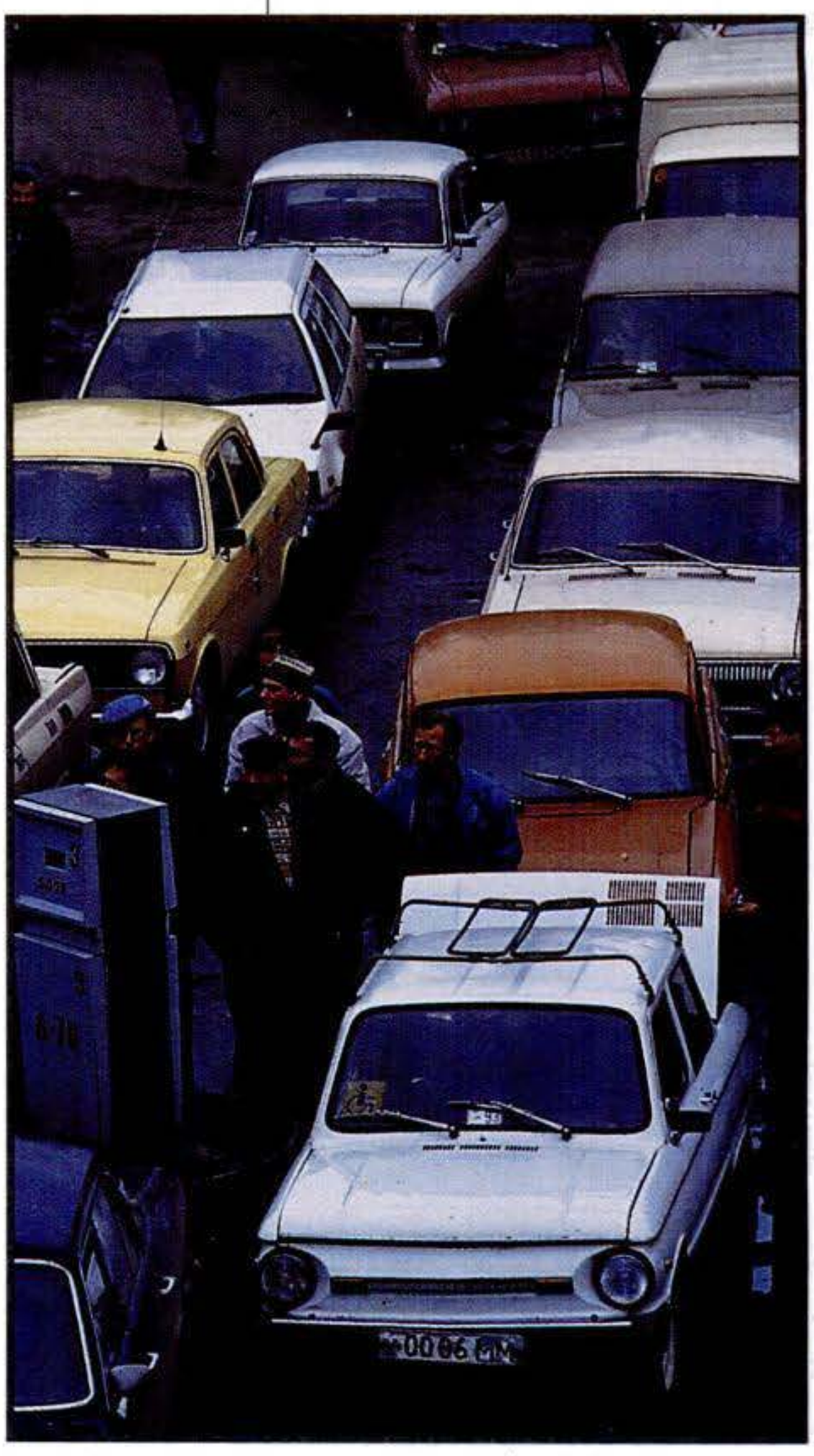
The Soviet Union did not really have factories dedicated exclusively to making civilian electronics and appliances. Instead, these were produced by small units of giant military factories. They were called "side products" and were not even counted in production figures.

For example, the military computer factory in Voronezh made VCRs, and a tank factory in the Urals produced electric meat grinders and microwave ovens. But these goods were always in short supply, available only on the black market or, with the appropriate connections, from the back door of the store.

[Continued on page 70]

ARTHUR FISHER

The Apple Macintosh computer is alive and well in Russia, for the few who can afford one.



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Auto fuel is dirty, expensive, and often in short supply, which causes long lines at the gas pumps.

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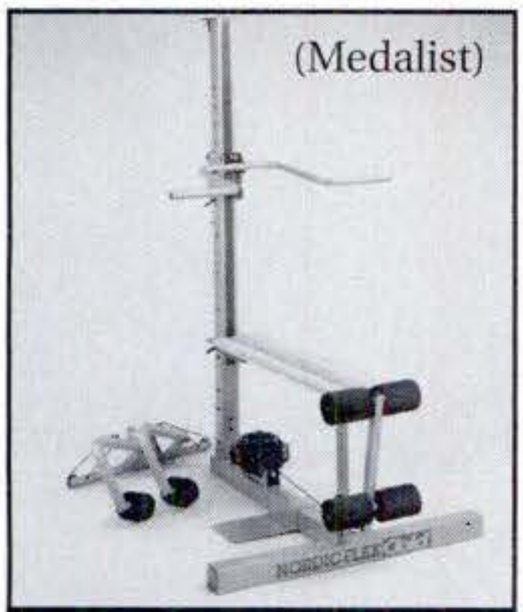

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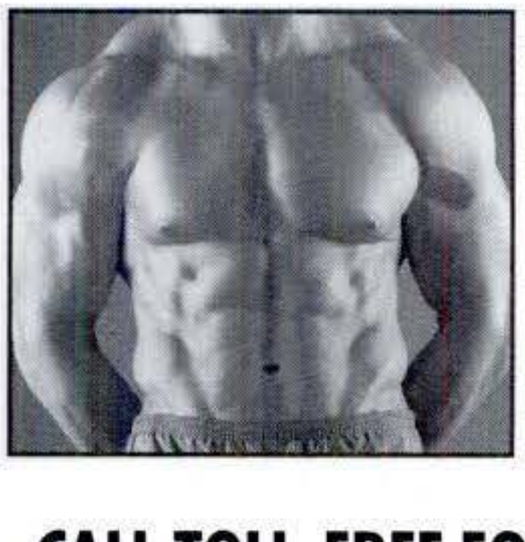

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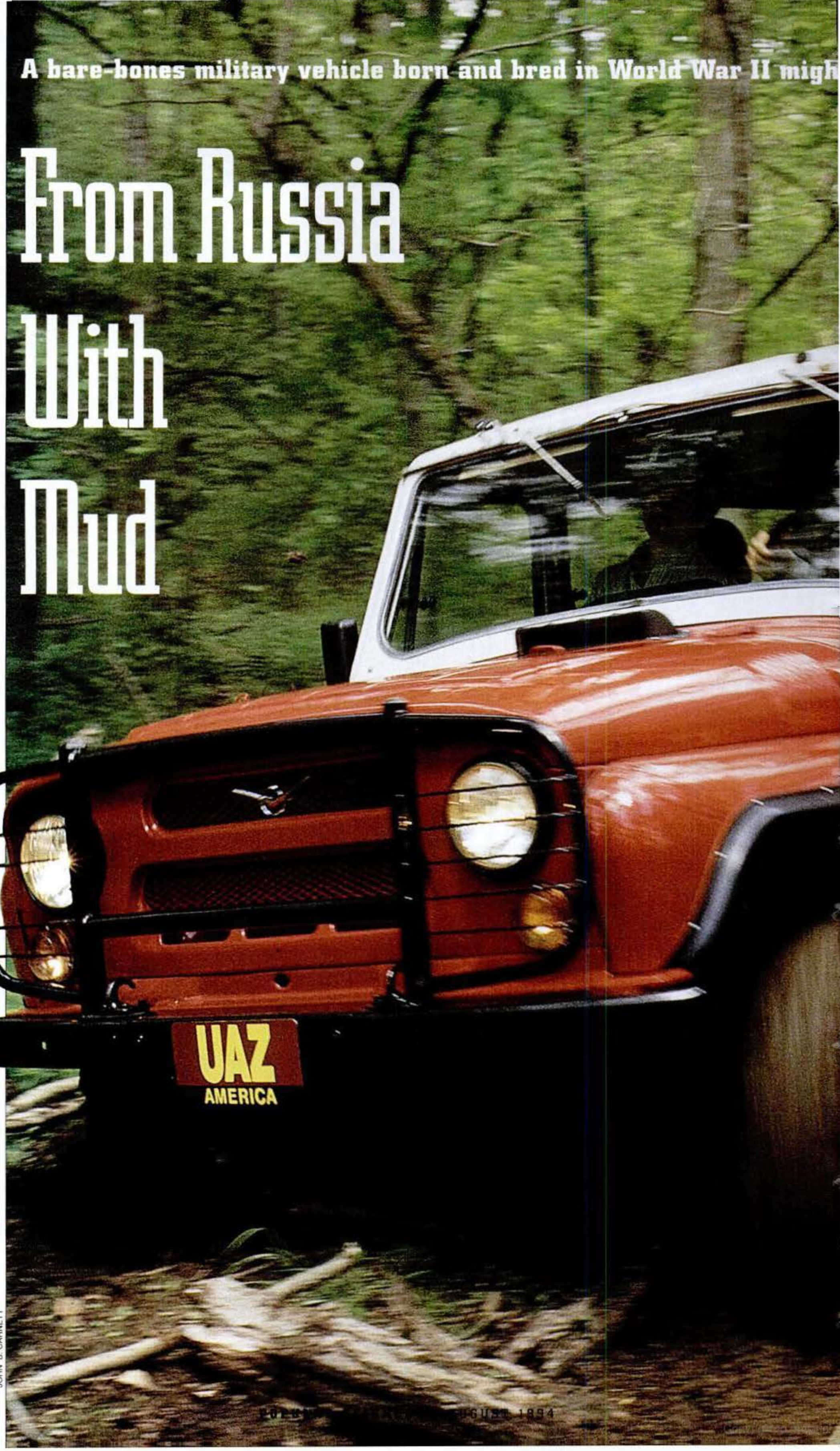
COUNTERPOINT

A bare-bones military vehicle born and bred in World War II migh

From Russia With Mud

America's Jeep, alike the UAZ, traces its roots to World War II. The two vehicles share some basic specifications: The Jeep's four-cylinder powerplant produces 123 horsepower, the UAZ's engine, 127 hp. Both use leaf-spring suspension front and rear. Wheelbase, overall length, and overall width are about the same for both vehicles. The Jeep, however, offers far more options, including automatic transmission, air conditioning, and a tilt steering wheel. Yet the Jeep's base price is about $2,000 less than the UAZ's.



JOHN B. CARNETT

Down and dirty: A husky, simple design doesn't pamper the driver, but it does give the UAZ an honest feel not found in other sport utility vehicles.

I mention to a Russian aquaintance that I'll be test-driving a UAZ, an all-wheel-drive Russian vehicle in production since World War II. He drains a tumbler of vodka, takes a long drag off a filterless cigarette, and peers at me. "My friend," he asks, "what have you done to deserve this punishment?"

The question echoes in my mind as I remove myself from the UAZ (pronounced ooh-AHS). After an hour of thrashing through the woods of Virginia, I feel like I've wrestled with a bear. My arms and shoulders ache, my left elbow is bruised, my kidneys jarred. And yet I never come close to pressing the tough little vehicle's performance envelope.

Unlike anything for sale in the West, with the exception of the Brobdingnagian Humvee, this vehicle was designed to follow tanks into the battlefield. The UAZ is heavy-gauge steel and iron Russian military ordnance that holds true to the military axiom, KISS: Keep It Simple, Stupid.

Sliding into the cockpit reveals KISS at its best. A cylindrical motor pinned to the top of the windshield runs the wipers. An old-fashioned choke graces the dash. A push button near the choke operates the headlights. Speedometer, oil pressure, and engine temperature are the only gauges.

A twist of the starter key brings the 91-horsepower four-cylinder Russian engine to life, and I navigate through the thicket of shift levers sprouting from the transmission tunnel: One lever selects all-wheel or two-wheel drive, another engages high or low four-wheel drive settings, and a third selects gears from the four-speed transmission.

The primary shift lever is canted away from the transmission centerline, so there's little tactile feedback when the drivetrain is engaged. A few runs across a flat field teach me how to interpret the odd sensations well enough to move through the gearbox.

We are heading into the woods when the terrain pitches down-

[Continued on page 77]

BY SANDY FRITZ

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COUNTERPOINT

Unlike Russian design philosophy that stresses strength, simplicity, and ease of repair on the flight lines of remote airfields, American military aircraft builders go all-out for high performance, pushing the development of complex new technologies and manufacturing methods, as with the F-117A.

Despite the dowdiness of its facilities, Russian aviation

Wings Over

BY BILL SWEETMAN

People whose identities were previously secret now grant interviews to foreigners in cities that once didn't even appear on maps. The doors to the former Soviet Union's aviation industry are open. And what lies within comes as nothing short of a revelation.

At Western aerospace companies and research labs, things are obsessively tidy, computers are everywhere, and swarms of efficient support staff take care of the details. Not so in Russia. Shocking wear and tear is apparent in almost every corner of the industry. Russian factories look like something out of the 1920s. Major aviation concerns operate from Dickensian offices. Even former showplaces—such as the air force base at Kubinka—are grimy, and the paint is peeling. Most of the major test facilities date to the 1960s, if not the 1950s.

Being welcomed into this world of woeful appearances can lead a visitor to the mistaken conclusion that good engineering couldn't possibly occur under such conditions, that Russian technological achievement has long been trailing the West. On the contrary: Russia has fielded much technology that equals or surpasses the West's best efforts.

Western military analysts have often gone astray by confusing the unsophistication of aircraft hardware with its actual capability. For example, when defector Lt. Viktor Belenko landed his MiG-25 fighter in Japan in September 1978, some commentators mocked the plane's seeming technical crudity. Instead of being built with titanium alloys, the fighter was made of steel (not even stainless!) and the radar was full of vacuum tubes (how primitive!).

These experts didn't realize that the welded-steel airframe of the MiG-25 was little, if any, heavier than a riveted titanium structure would be, and much less costly to build. It was a smart design choice. Western engineers had already tried and failed at using steel for high-speed aircraft.

The missing ingredient was Russia's advanced welding technology—by far the best in the world. And when the MiG-25 radar was designed in the 1960s, vacuum tubes were still a logical alternative to solid-state electronics for such high-power applications. Again, the engineers had chosen what worked and could be serviced easily. In short, Russian design philosophy has long stressed a different goal: strength, simplicity, and ease of repair on the flight lines of remote airfields.

Practical concerns continue to guide Russia's style of aviation engineering. In a recent interview in Moscow, Rostislav Belyakov, general designer of the Mikoyan Gurevich (MiG) design bureau, spoke quite matter-of-factly about the value of

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Wheels go up, as a MiG-29 fighter climbs with afterburners lit.

engineering equals or surpasses the West's.

Russia

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stealth in the design of a next-generation tactical fighter. He says a successor to the current MiG-29 fighter will feature a carefully tailored level of stealth, just enough to gain the advantage of surprise in combat without sacrificing flight performance. The U.S. Air Force's new Lockheed F-22 advanced tactical fighter, Belyakov comments, "has achieved this compromise to some extent."

A conservative engineer such as Belyakov does not talk like this unless he has hard data to back up his statements. The idea of a stealth fighter was first publicly mentioned in the United States 20 years ago. Thus, it is only reasonable to assume that the Russians have been working on stealth technology for approximately that long. Prototype aircraft may have been flown. At the very least, test ranges will have been built to measure the radar visibility of large-scale models or full-size aircraft. This work, of course, is conducted in secret.

Russian engineers have often shown a remarkable ability to develop simple solutions to complicated problems. As Russia's leading early helicopter designer, Mikhail Mil, used to put it: "Make it simple, make it strong —and make it work!" The open window of glasnost at last lets us see how this is done.

The Russian aviation industry has a unique structure that shapes the way the engineering process is conducted. Although MiG, Sukhoi, and the other great names of Russian aviation now wear the Western-style label of "joint-stock company," the enterprises still function much as they did when they were officially known as design bureaus.

The design bureaus resemble Lockheed Corp.'s small, fast-working Skunk Works special projects division more than they do a typical Western aircraft company. Their function is to design, build, and test prototype aircraft that meet government requirements. Once the design is proven, it is transferred to a state aircraft factory for production.

Another feature distinguishes the design bureaus; they work very closely with massive state research institutes, which have no exact equivalents in the West. Some 15 miles from Moscow, for example, is the city of Zhukhovsky, named after Nikolai Zhukhovsky, a professor at Moscow's Technical College, who founded Russia's first aerodynamic research institute in 1918.

Until the late 1980s, the city and its surroundings were closed to foreigners, because it was built to house the Central Aero-Hydrodynamic Institute (TsAGI). TsAGI has more than 20 wind tunnels, including the world's second-largest tunnel and the world's best hypersonic tunnels. It also performs the structural testing of all new Russian aircraft.

A few miles away is the airfield where most Russian aircraft make their first flights. For many years, its proper name was unknown in the West. Now we know this test facility is called Zhukhovsky airfield, home of the Flight Research Institute (LII).

TsAGI works on basic aeronautical theory and develops test facilities to explore how theoretical principles translate into actual designs. The results are then made available to the design bureaus. Finally, TsAGI and LII test and approve the bureaus' work before an aircraft goes onto a production line.

How well does this system actually work? The remarkable agility of the formidable MiG-29 and Su-27 fighters has dazzled crowds at air shows worldwide. In the now-famous Cobra maneuver, performed by both types of fighters, the pilot begins by pulling the control stick fully aft during level flight at medium speed. The airplane's nose rotates upward until the craft seems ready to flop over on its back. The airflow, which is now almost perpendicular to the horizontal stabilizers on the tail, finally forces the nose back down, and the air-

BILL SWEETMAN

The Sukhoi-29 aerobatic plane (above) has shown pilots can tolerate more than nine g forces. The nose of the Sukhoi-100 supersonic bomber droops for pilot visibility during landing.

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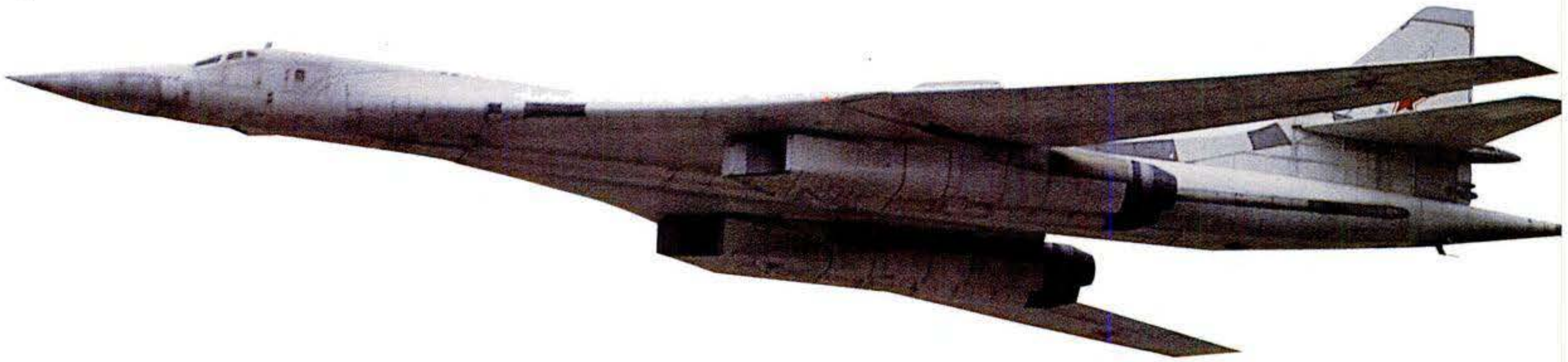

HANS HALBERSTADT / ARMS COMMUNICATIONS

craft levels out from a shallow dive. It's a sight to behold.

Western fighters can perform a Cobra maneuver too. But only the Russians do it at air shows, because their fighters are much more stable at extremely high nose angles. A Russian pilot can perform the maneuver without worrying that the aircraft's nose will suddenly "slice" to the left or right. And he knows that recovery will be assured and easy, because the engines will continue to run, even with their air inlets moving slowly at a right angle to the airstream.

Although Belyakov himself views the Cobra maneuver as a show tactic that might actually get a pilot killed in combat by putting him onto a slow and predictable flight path an enemy could exploit, it provides vivid proof of the aerodynamic and engine stability of the Russian fighters. During a dogfight, these qualities mean the aircraft can be flown to their limits without loss of control.

Good aerodynamics and engine behavior are not flukes. They are the result of intensive study that starts early in an airplane development program, long before first flight. Unlike most Western designers, Russian engineers use rocket-launched, free-flight models of each new fighter design to determine how the aircraft will handle if it exceeds its aerodynamic limits and enters a spin.

The Western discovery of a particularly innovative piece of Russian test equipment is related by Sergei Sikorsky, son of helicopter pioneer Igor Sikorsky. For many years, the younger Sikorsky has served as an ambassador-at-large for Connecticut-based United Technologies and as one of the most experienced Western observers of Russian aviation. In the 1970s, a drawing appeared on the back page of a Soviet aerospace magazine that showed the whirling wakes, or vortices, shed by the tips of a helicopter's spinning rotor. "Each individual blade had vortices. It was detail that we did not have," Sikorsky recalls. "Half our engineers thought the Russians knew things we did not know, and the other half thought it was bull."

Much later, it was learned that the Russians had achieved a breakthrough in the study of helicopter aerodynamics. They were testing rotor models in vertical water tunnels, under conditions that caused the flow to cavitate—that is, generate small bubbles. Special photographic

Russia's supersonic Tu-160 swing-wing bomber resembles the U.S. B-1, but efficiently flies much faster at high altitudes.

BILL SWEETMAN

The Sukhoi-27 (above) is one of the world's best fighters. An advanced Su-35 prototype (below) adds canard fore-plane control surfaces.

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techniques recorded the vortices traced by lines of bubbles.

Russian industry has evolved its own distinct methods for flight-testing new aircraft. In the West, the limits of controlled flight are usually established theoretically and by wind-tunnel tests. They are only approached with caution. Stalls are seldom performed intentionally, except during level flight. By contrast, Russian fighters are repeatedly stalled and put into spins during flight testing.

Such spins are dangerous. Several prototypes of the swing-wing MiG-23 crashed during spin tests. However, notes MiG test pilot Valery Menitsky, the changes made as a result ensured that no operational MiG-23 was ever lost as a result of a stall and spin.

In the case of the MiG-29, these tests allowed the designers to adjust the control system to make the aircraft more resistant to spinning. Also, two very small delta-shaped strakes were added near the tip of the nose. These fins generate a vortex, or whirling airflow like a small tornado, on each side of the aircraft. During sharp maneuvers, they help to control airflow over the wing, making a spin less likely.

Engine stability, like aerodynamic predictability, stems from fundamental research and testing. At Tuarevo, ten miles from Moscow, the Central Institute for Aviation Motors (TsIAM) maintains a massive complex of engine test cells. The facility has arrays of motors, compressors, heaters, and coolers that can test full-size engines at conditions that duplicate the cold, low-pressure air of high altitudes and the extreme heat and pressures in an engine during supersonic flight.

One of the perennial problems of jet, or turbine, engine design is instability in the compressor section. Like an airplane's wing, a turbine engine's whirling compressor blades can stall under heavy or fluctuating loads, causing the engine to lose power or flame out entirely. Unfortunately, compressor stall is often not detected until an engine is built and run at full power.

Since 1956, TsIAM has operated a massive 100,000-horsepower rig that can test the compressor to maximum power before it is installed in an engine. One of the Institute's engine test cells is equipped with another unique device called a distortion generator, which consists of a fast-acting set of heavy-duty shutters that partially block the flow of air into the engine. It simulates the conditions the engine will encounter as the aircraft maneuvers at various speeds and altitudes, and as the angle of the airflow into the inlet changes.

Part of the TsAGI site is covered with large spherical air tanks that feed the T-117 hypersonic wind tunnel, a facility Russian engineers use in the design of hypersonic aircraft and spaceplanes. It is the only wind tunnel in the world that combines a near-orbital Mach 20 maximum speed with a three-foot-square working area for test models. Temperatures in the tunnel can reach almost 3,200°F, simulating the friction heating caused by hypersonic flight.

TsAGI works closely with TsIAM on hypersonic aircraft projects. TsIAM's achievements include the first known flight of an aircraft with an air-breathing jet engine fueled by liquid hydrogen. In 1991 and 1992, TsIAM carried out the first and only successful flight tests of a working supersonic combustion ramjet, or scramjet, engine for ultra-high-speed flight.

The wingless, cylindrical TsIAM scramjet vehicle was launched from an S-200 surface-to-air missile at 4,000 mph and 60,000 feet. According to TsIAM deputy director Vladimir A. Sosounov, the test results closely matched predictions made using the computer modeling method known as computational fluid dynamics.

The next step in the TsIAM program is a seven-ton, 28-foot-long delta-winged research vehicle that would be launched by a surplus intercontinental ballistic missile booster and recovered using a parachute. It could attain a speed as high as Mach 16, or 10,500 mph, at an altitude of 100,000 feet.

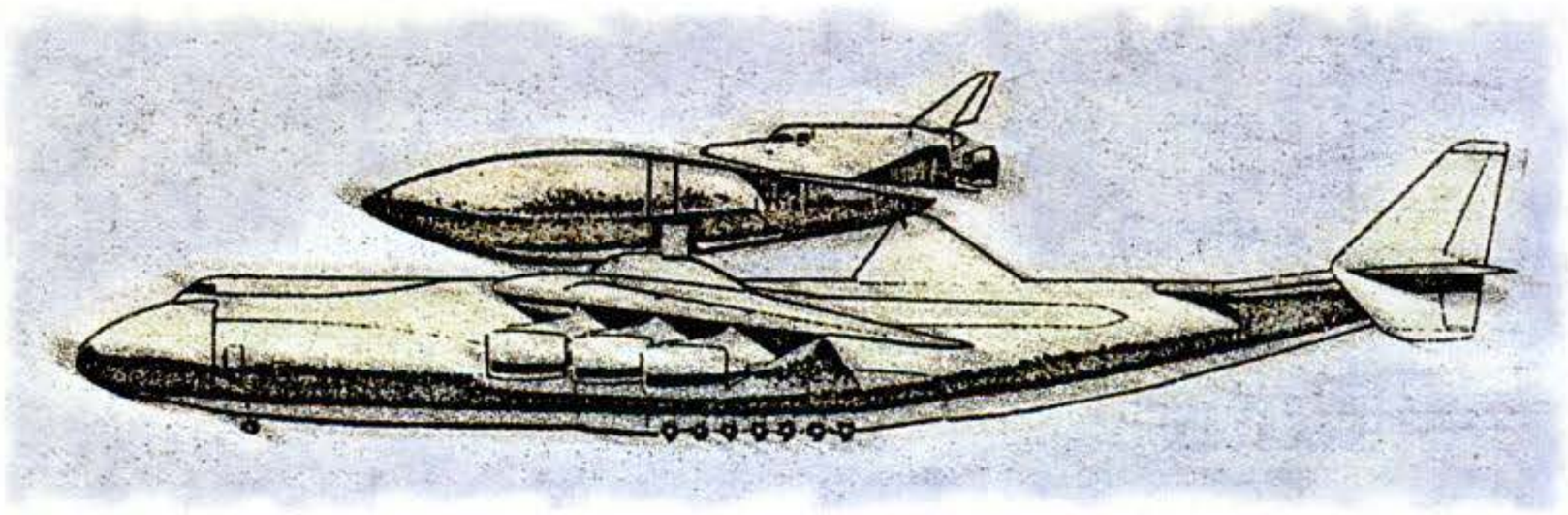
Russian officials are looking for international partners for this project. Zagainov of TsAGI believes that a fully reusable winged space launcher "should be a truly international system, which can be flown to whichever country is the customer" to collect a payload and fly it into orbit.

Zagainov is a strong believer in craft that can take off from runways rather than launching pads. "The system is cheaper, more flexible, and more mobile," he says, and "four or five recovery airfields worldwide are enough to ensure a safe landing." Traditional pad-launched spacecraft, he feels, will only be used for very heavy payloads.

Russian engineers concluded in 1990 that the now-canceled, single-stage-to-orbit U.S. X-30 National Aerospace Plane would not be able to carry a payload into orbit. Such a craft is "an aim of the distant future, unless there is some technological miracle," Zagainov says.

Spaceplane development, Zagainov feels, should proceed in three phases, the first being a two-stage vehicle with a subsonic first stage, such as the giant An-225 Mriya transport plane, with its 250-ton payload. The next phase would use a hypersonic first stage. "After that," he says, "it is practical to talk about single-stage-to-orbit."

The European Space Agency has been looking to Russia for help with its own spaceplane effort. Heinz A. Pfeffer of ESA expresses what many outside observers now say about Russia's aviation technology: It embraces some solutions that have simply not been thought of, or properly investigated, in the West. "What I look for from the Russians," says Pfeffer, "is the 'Aha!' factor." PS



TOM WHITE

Russian engineers propose a two-stage launch system called MAKS, using a hydrogen-fueled rocket spaceplane mounted atop a huge Antonov-225 Mriya transport aircraft.

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THE EKRANOPLANE: RUSSIA'S WINGSHIP

Russian aviation engineers have implemented a long-overlooked flight technology. They propose that huge, sea-skimming craft can be built to whisk freight or passengers across the oceans at 450 mph, while burning only about half the fuel of today's jetliners. And sprawling, expensive airports aren't needed—just minimal handling facilities at water's edge. It's an idea that could create a new transportation industry, half-airplane, half-ship.

The Russians are the world's undisputed experts in this field of ground-effect flight. Thirty years of secret work has produced machines they call Ekranoplanes, which range from small trainers up to the massive 544-ton "Caspian Sea Monster," an operational craft as big as the U.S. C-5A military transport. Ekranoplanes have been used for missions including river and maritime patrol, antisubmarine warfare, naval surface attack, and passenger transport.

Western specialists were puzzled when they learned of the Caspian Sea Monster. A study done long ago for the U.S. Army had shown that a wing thick enough to generate the lift necessary for takeoff from water would be uneconomical for ground-effect cruising. The idea was dropped. What had the Russians discovered?

Their method was to direct the exhaust of the jet engines into the underwing space, generating high pressure there. This was sufficient to lift the craft at a standstill and get it moving, all with a wing thin enough for low drag at cruising speed.

Ekranoplanes operate with their wings very close to earth or sea, in a condition known as ground effect, which boosts lift and cuts drag. Lift increases because the wing and the surface over which it flies trap air between them, causing underwing pressure to rise. Drag decreases because the presence of the nearby surface is used to suppress formation of whirling air vortices that sap the efficiency of normal wings.

A wing in ground effect is like a plain bearing that supports a car's crankshaft by climbing onto a wedge of oil, whose viscosity prevents it from being immediately squeezed out. The continuously replenished oil film in the bearing supports the load, preventing destructive contact between moving parts. The moving wing of the Ekranoplane is, therefore, just a large "air bearing."

The Russians see applications for their existing Ekranoplanes in fast inter-island service and search-and-rescue missions. Although these designs are too small to achieve the full potential benefits of ground effect, they could be economically viable, because they need no airports. Cooperative development of a huge, next-generation transoceanic craft is being pushed by Aerocon Corp., in Arlington, Va., which has attracted some support from the Pentagon's Advanced Research Projects Agency. Military interest has been sparked by the logistical needs of overseas buildups such as Desert Storm, where a fast and efficient heavy cargo mover is essential.

Steve Hooker, the company's president, has researched gigantic 4,000 to 6,000-ton "wingships" flying at 15- to 30-foot altitudes over distances of 5,000 miles or more.

How does this compare with today's big airplane, the Boeing 747? The 747 takes off at just under 400 tons and flies at about 570 mph to deliver 50 tons of cargo over 5,000 miles. The proposed wingship would have 12 times the weight of a 747, yet carry 30 times the payload.

The big payload gain comes partly from the low-drag benefits of flying in ground effect and partly from the efficient structural design a wingship can have. To maximize efficiency, a conventional airplane's wing must be long and slender, but it takes lots of heavy material to make such a wing strong. The heavier the payload, the more wing structure is needed to support it.

By flying in ground effect, the Ekranoplane or wingship can develop lift efficiently with short wings made strong with less material. The payoff is more payload. Ongoing computer simulations and years of flight experience have made Russia's Ekranoplane engineers and their American partner anxious to prove the wingship idea in metal on a grand scale.—*Kevin Cameron*

A proposed transoceanic "wingship" (above). A water-skimming Ekranoplane departs from a ramp (below).

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COUNTERPOINT

Last December, Energy Secretary Hazel O'Leary disclosed that the United States has produced 102 metric tons of plutonium, 66 of them made between 1944 and 1987 at the Hanford nuclear reservation. Now a physicist at the Natural Resources Defense Council calculates that the facility had actually produced 67.5 metric tons of plutonium. The extra 1.5 metric tons are enough to make hundreds of weapons. DOE officials say the discrepancy is a result of shoddy bookkeeping, not theft.

Nuclear Chaos

The prospect of nuclear war is fading. But nuclear weapons

If there was one area in which the Soviet Union truly excelled—quantitatively if not qualitatively—it was in the development of nuclear energy for war and peace.

Marxism-Leninism depended upon the "means of production," the industrial system that nourished communist society, and that system had to be strengthened and protected at all cost. This in turn depended upon generating immense amounts of energy to keep farms and factories operating, and producing weapons so destructive that the West would not dare attack. All of the republics except Azerbaijan, Moldova, and Turkmenistan produced nuclear weapons and power plants, or the research and materials that went into them.

Like the space program, atomic energy yielded enormous prestige—propaganda that played especially well to nonaligned nations like India and Egypt, which Moscow courted. But in reality, the Soviet Union's love affair with nuclear energy exacted a horrendous cost upon individuals and the environment, both of which were considered far less important than sustaining the means of production. The Soviet nuclear legacy continues to pose an incalculable threat to world stability because of thousands of unemployed or underemployed atomic scientists who are seeking work, plus an immense stockpile of salable, finished weapons and weapons-ready fissile material.

TOM WHITE / FPG

While widespread contamination of the environment will be the nuclear program's longest-lasting legacy, the most pernicious short-term danger comes from a burgeoning horde of criminals and corrupt officials who are eager to sell their country's nuclear stocks to foreigners for hard currency. The entrepreneurs, from lone freelancers to pervasive organized crime syndicates, threaten to add new meaning to "make a killing."

Although the government

BY WILLIAM E. BURROWS

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A catastrophic accident at the Chernobyl power plant in 1986 focused the world's attention on unsafe Soviet reactor designs.

radioactive waste, and poorly designed reactors are here to stay.

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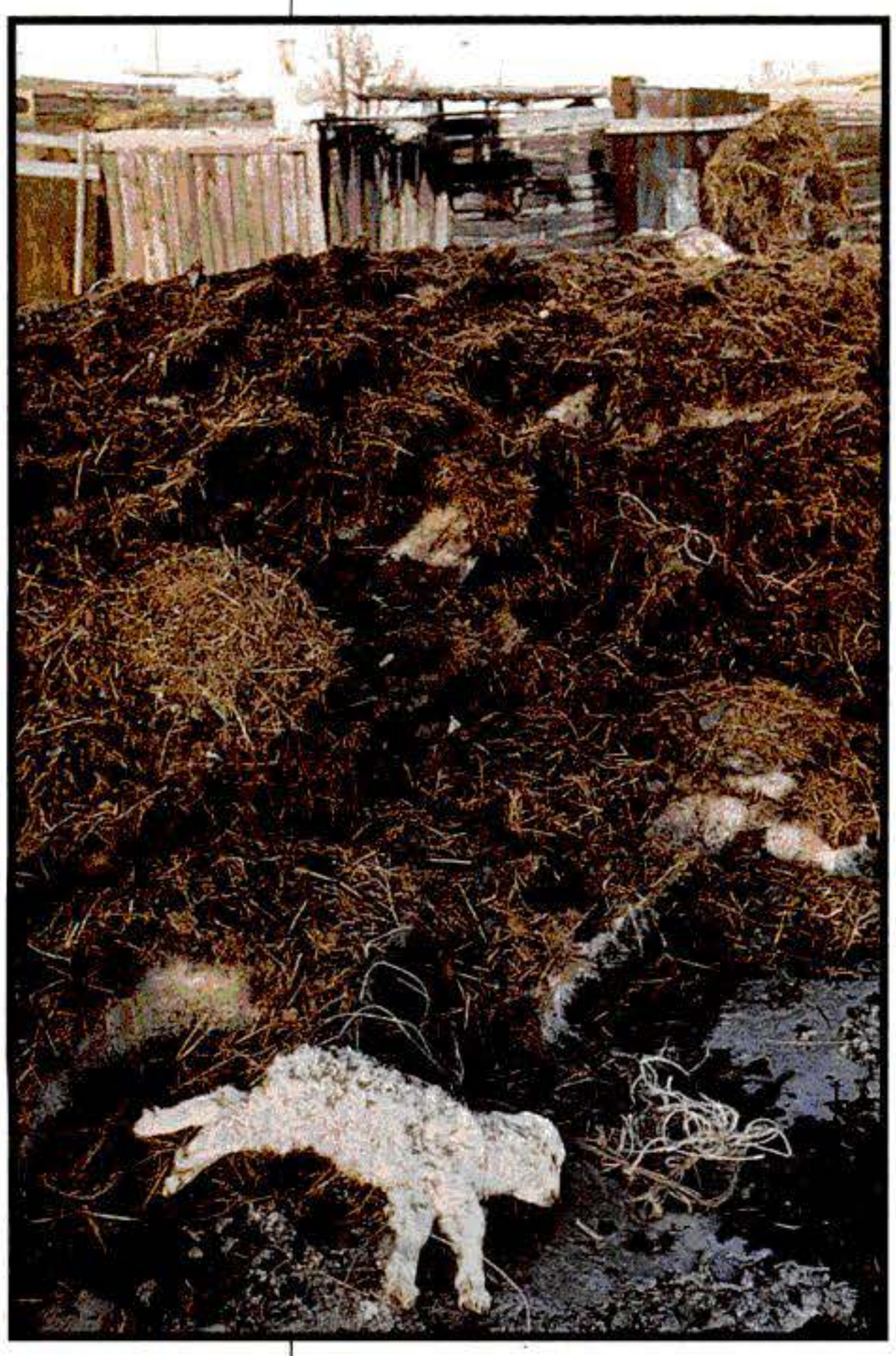
seems to have kept a shaky lid on its fissile material and nuclear weapons stockpile so far, the situation is as unstable as bomb-grade plutonium itself. The wheeler-dealers know that, where Iraq, Iran, Libya, and other would-be nuclear weapons states are concerned, plutonium and highly enriched uranium are more than worth their weight in gold.

In common with some of their American counterparts, Soviet engineers in the 1940s and 50s believed that the atom held so much energy that it would someday be too cheap to meter. But there were other, more subtle, reasons for harnessing nuclear



PAUL LOWE / NETWORK / MATRIX

Sheep in Kainar, Kazakhstan, died from radiation poisoning during the Soviet Union's nuclear testing program.

power. For one thing, it required advanced science and technology, which proved to the workers and peasants at home that the doctrine controlling their lives was the wave of the future and would make their nation a people's paradise.

"Comrades, look at what a beautiful city you have here in Pripyat," said Vladimir Mikhailovich Tsybulko, a high-ranking member of the Ukrainian Communist Party, in 1979. "You have been talking about four reactor units," he added, in reference to a power-plant complex planned for a site close to the city. "I say that's not enough! I would build eight, twelve, and even all twenty reactor units! Then the town will grow to one hundred thousand inhabitants. It will be a fairy tale, not a town." The fairy tale turned out to be a grim one. The four reactors that did go on line were named Chernobyl.

The infamous accident at the Chernobyl-4 reactor on April 26, 1986, was the first dramatic indication that many Soviet power reactors were inherently dangerous. Technicians were testing the reactor—a type that is cooled by water and whose neutron flux is moderated by graphite—to see whether its turbogenerator could provide power after the steam supply was shut off for a short time. But the experiment suddenly went out of control, turning into a 44-second "power excursion" that caused the reactor to literally blow its top. About 50 tons of nuclear fuel evaporated in the explosion and were released into the atmosphere, contaminating a wide swath of Ukraine and spreading to Sweden and beyond. Millions were exposed to iodine-131, plutonium-239, cesium-137, strontium-90, and other radionuclides.

Some workers volunteered to clean up the still-smoking, radioactive rubble within hours of the accident; others "volunteered" at gunpoint. Dramatic pictures taken within hours of the accident show men, whose only protection against radiation was surgical-type masks, tossing chunks of "hot" graphite off the roof of the reactor building with their bare hands. Others photographed the scene from helicopters hovering in the severely contaminated smoke pouring out of the jagged hole. Some died quickly of massive exposure to radiation. Others continue to die.

Moscow's first reaction was to blame the catastrophe on those who conducted the experiment. But Marxist technology was the true culprit. Not only was the reactor's design inherently faulty, but even the containment that was supposed to keep radioactive particles from escaping into the atmosphere was pathetically thin. While the containment on U.S. reactors is made of thick reinforced concrete, Chernobyl's was only flimsy sheet metal.

"You could plainly see blue sky through the cracks in the [containment] ceiling when you stood inside," says Gregory J. Van Tuyle, a Brookhaven National Laboratory scientist who helped determine the cause of the accident for the U.S. Department of Energy. Citing the incessant meddling of ignorant bureaucrats, Chernobyl's chief engineer, Grigori Medvedev, called its design "a death sentence waiting to be executed."

Sixty-two Soviet-designed power reactors continue to operate in the former Soviet republics and Eastern Europe. Forty-seven are pressurized water reactors, called VVERs, that are similar in principle to most American types. But the older VVERs, the model 230 and the slightly newer 213, lack real containments, as well as emergency core cooling systems to pump in extra water if a pipe ruptures. The other 15, all of them similar in design to Chernobyl-4, are considered so dangerous that American and other Western experts have called for taking them off line.

In April, Ukraine tentatively agreed under pressure from the United States to shut down Chernobyl's two remaining operational reactors. It also agreed to form a partnership with Westinghouse Electric Corp. to upgrade the safety level of its 14 VVER reactors with $5 million in start-up funds provided by the U.S. Department of Defense. Westinghouse is undertaking the same kind of project on VVERs in the Czech Republic. Critics of that plan, including Friends of the Earth, claim that it amounts to slapping Band-Aids on reactors that are so inherently unsafe that no amount of fixes can make them otherwise.

The reactors and the fuel cycle that supports them constitute a specter of unimaginably frightening proportion. Yuri Vishnevsky, chairman of Russia's Atomic Industry Inspectorate, said in February that widespread safety violations, poorly trained workers, thefts of radioactive material, and abiding poverty have created an "intolerable" national hazard.

He reported that about 20,000 safety rule violations were recorded in 1993, and that nuclear facilities were forced to

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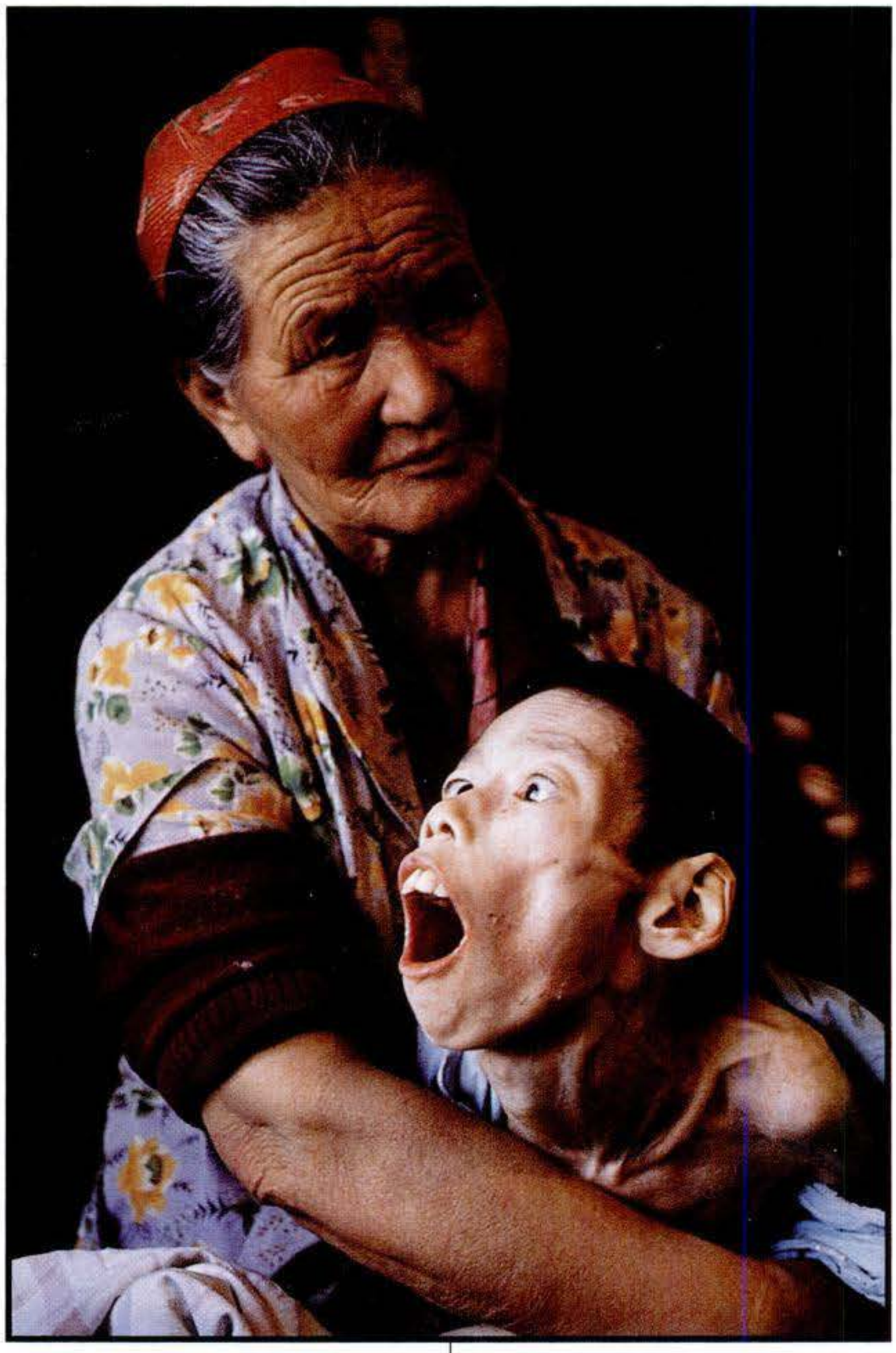
shut down 78 times that year because of extremely dangerous operations. Nearly 10 percent of 5,000 workers flunked a test of safety rules, Vishnevsky said, adding that the maximum fine for an individual who violates safety regulations is 100 rubles, or about 5 cents.

So pressed are the Russians for money that a company was set up in Moscow in 1990 to allegedly "use nukes for nature." It promoted the idea of incinerating toxic wastes, including the radioactive kind, with underground atomic explosions.

Called the International Chetek Corp. (an abbreviation of Chelovek, Technologia, Kapital —the Russian words for Man, Technology, Capital), the outfit was started by nuclear program managers and scientists in a desperate effort to market skills that were no longer needed to wage the Cold War. The U.S.-Russian moratorium on underground nuclear testing has stalled the disposal plan, which company officials insist is good for the environment. They take the dubious position that because the blasts would occur in large rock formations, nuclear contamination would be all but eliminated. Environmental groups are not persuaded.



PAUL LOWE / NETWORK / MATRIX

Nuclear test victims in Sarjal, Kazakhstan, suffer from a wasting disease that resembles AIDS.

The full extent of nuclear pollution, which was kept under the tightly drawn shroud of state security before perestroika, is still not completely known. What is known, however, is hair-raising. From the beginning of their nuclear program in the 1940s to as late as last October, when a freighter was caught dumping low-level radioactive waste into the Sea of Japan, the Russians have systematically turned much of their own territory and the seas around it into a convenient nuclear cesspool. A report presented to the International Maritime Organization by Russian scientists last autumn admitted that "all dumpings...in the northern seas (and most dumpings in the far eastern seas) were performed in gross violation of international standards."

One of the worst horror stories concerns Novaya Zemlya, a 500-mile-long island that thrusts into the Barents Sea like a curved scar. For years, the Soviet military used the waters on both sides of Novaya Zemlya as a dumping ground for nuclear reactors from 18 nuclear submarines and icebreakers, in spite of a 1972 ban on such activities. Eight of the reactors contained hot fuel. Uncounted canisters of nuclear waste were also pitched into the waters, nuclear bombs were tested there, and an entire nuclear sub was deliberately sunk after an accident in May 1968.

Another submarine, the *Komsomolets*, sank 300 miles off Norway, with the loss of 42 sailors, after a fire in 1989. Equipped with two nuclear warheads, the sub is leaking small amounts of highly radioactive plutonium-239 that could contaminate commercial fish stocks in the area. Russian scientists have asked for international help to raise the wreck, or to seal it with a gel that would harden in contact with seawater.

Additional nuclear wastes have ended up in lakes, rivers, and leaking underground storage tanks. The effects of Chernobyl pale in comparison with the effects of a nuclear weapons program that peaked in 1986 at 45,000 bombs, warheads, mines, artillery rounds, and even "backpack" devices to be worn by atomic commandos behind enemy lines.

These nuclear weapons were produced in the notorious secret cities, a vast network of research, design, production, testing, and storage sites spread across the breadth of the motherland. Tomsk-7, Arzamas-16, Chelyabinsk-70, and other secret cities bore only postal numbers, and were not found on any maps. Many were built with slave labor and manned by political prisoners: "special contingents" of the kind that were memorialized by Aleksandr Solzhenitsyn in *The Gulag Archipelago*.

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SOVFOTO

Russia has a large arsenal of intercontinental ballistic missiles, like the one in this silo, which have not yet been dismantled.

"From 1955 to 1989, I was a nonperson who worked at a place that didn't exist," one noted geophysicist recalls with a rueful smile. His job was to monitor his own country's nuclear weapons tests at Semipalatinsk, and those of its main adversaries in the Nevada desert and at Lop Nor in western China.

Accidents were not uncommon in Russia's secret cities. One of the worst happened in 1957 at Kyshtym, a plutonium production site near the city of Chelyabinsk in the Ural Mountains. High-level waste solutions in a concrete tank submerged in water got so hot they exploded, blowing off a yard-thick concrete lid and releasing 70 to 80 metric tons of radioactive waste into the atmosphere. Some 217 towns and villages in the area, with a combined population of 270,000, were so radioactively contaminated they had to be evacuated.

The accident was revealed to the West in 1976 by dissident scientist Zhores Medvedev, but was not confirmed by Russian authorities until 1989. They estimated that four times as much radioactivity had been released as at Chernobyl.

Many secret cities were Chernobyls in slow motion. In the early 1950s, the Chelyabinsk plant discharged high-level radioactive waste directly into the Techa River near Sverdlovsk, some of it making its way 1,000 miles to the Arctic Ocean. Later, waste was dumped into Lake Karachay, which has no outlets. The lake has received more than twice the radioactivity emitted by the Chernobyl accident, according to D. J. Peterson of the Center for Soviet Studies in Santa Monica, Calif. When the lake dried up briefly in 1967, much of the contamination blew across farming villages up to 60 miles away.

But the contamination of fields, streams, and oceans by radioactive byproducts is not the only problem. There is also the fissionable material itself. More than 125 metric tons of bomb-grade plutonium are stored at Chelyabinsk and Tomsk, enough to make 15,000 new warheads or bomb cores. Some of the plutonium is raw; some is machined into perfect spheres. Another 1,000 metric tons of highly enriched uranium—enough for 45,000 additional weapons—is stashed at Sverdlovsk, Angarsk, Krasnoyarsk, and Tomsk.

No one seriously believes that Russia intends to manufacture 60,000 more bombs and warheads. On the contrary, the Kremlin is eager to dismantle much of the weaponry it already possesses and sell the nuclear cores as civilian reactor fuel in the United States and elsewhere. The problem is that the plutonium and uranium are more valuable as bomb components than as fuel and could therefore be subject to theft or sale by underpaid and demoralized security guards.

"Russia and the United States must deal with tens of tons of excess plutonium, the result of the ongoing dismantlement of thousands upon thousands of nuclear weapons," said John H. Gibbons, President Clinton's science adviser, in a recent speech. The United States tried to ease the problem in 1992 when it agreed to help build a central depository at Tomsk for all of Russia's nuclear material.

The 60-acre underground facility would consist of 50 two-story halls, each 75 yards long. Each hall would hold 2,000 canisters, each of which would contain up to 11 pounds of plutonium or twice that much highly enriched uranium. Trains running aboveground would deliver the canisters to both ends of the gargantuan facility, where elevators would lower them to what is hoped will be their final burial place. For now, however, the depository remains nothing more than an ambitious plan.

Few of the former Soviet Union's warheads have been dismantled. By 1989, when the death knell of Soviet communism abruptly ended superweapon production and relegated most conventional weapons like the MiG-29 to a colossal yard sale, there were some 35 different types of offensive nuclear missiles (not counting those used in aerial combat). These ranged from submarine- and air-launched cruise missiles, to the venerable (and ever-popular) medium-range Scud, to

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the huge SS-18 Satan. The last is a 120-foot-long monster that carries up to ten independently targetable warheads. It was designed specifically for use against "hard targets" such as U.S. missile silos.

The newer SS-24 Scalpel and SS-25 Sickle have ranges slightly shorter than the SS-18's 6,000 nautical miles, but they also have a striking advantage over their older, more cumbersome cousin: They are launchable from railroad cars and are therefore highly mobile.

Four nations—Russia, Ukraine, Kazakhstan, and Belarus—owned long-range, nuclear-tipped, ballistic missiles when the Soviet Union disintegrated into its 15 constituent parts. Belarus relinquished all 72 of its SS-25s in 1992. Kazakhstan had 104 SS-18s and 40 TU-95 Bear bombers armed with nuclear-tipped AS-15 cruise missiles when the empire crumbled, but it returned them to Moscow and signed the nuclear Non-Proliferation Treaty banning the spread of nuclear weapons. Kazakhstan also agreed with five other former Soviet republics to control exports of material, technology, and equipment that could be used for making weapons of mass destruction.

Both pledges are particularly important because Kazakhstan contains a formidable nuclear weapons infrastructure that is not so easily moved as missiles and bombers. It has the giant Tyuratam cosmodrome and missile launch facility, the sprawling Semipalatinsk test complex, a fast breeder reactor used for producing plutonium, two giant uranium mining centers, and extensive nuclear research and fuel fabrication facilities.

Ukraine's nuclear stockpile is a thorny problem. The home of a proud, nationalistic people who have always resented Russian domination and remain suspicious of Moscow, Ukraine emerged from the collapse of the Soviet Union with a fearsome arsenal of nuclear weapons and, like Kazakhstan, a research and development infrastructure to match.

While Ukraine agreed to dismantle all 130 of its SS-19 Stiletto intercontinental ballistic missiles, it stubbornly held onto 46 SS-24s, 34 TU-95 and TU-150 bombers (the latter is a supersonic equivalent of the U.S. B-1B), and an unspecified number of nuclear gravity bombs. Nationalist legislators were clear about their reasons for wanting to hang onto the superweapons: to use them as bargaining chips to pry aid out of Washington for their beleaguered country. Meanwhile, the more liberal president, Leonid M. Kravchuk, resolved in September 1993 to dismantle all of the warheads so their cores could be used to fuel the reactors of a desperately energy-hungry Ukraine. In the end, Kravchuk had his way when parliament voted to sign the START treaty reducing nuclear

[Continued on page 76]

PHOTOS BY SOVFOTO

Nuclear submarines of the northern fleet (above) rarely patrol the seas anymore. Below is a Russian-designed 100-megaton nuclear bomb.

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One benchmark for defining a supercomputer is cost: Anything that sells for $10 million or more is a supercomputer. This category includes machines made by Cray, Convex, Fujitsu, Hitachi, and NEC. The Cray-YMP/C9016 (with 16 processors) is rated at 16 gigaflops. According to the International Data Corp., 193 such supercomputers are in use in the United States; plus 883 minicomputers rated at about one gigaflops (such as less-powerful Crays); and 1,037 massively parallel computers (such as those from Thinking Machines).

DAN MILLS

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Computer Czar

BY ARTHUR FISHER

Boris Babaian, holder of the Lenin Prize, father of high-powered computing in the Soviet Union, has formed a symbiotic relationship with America's Silicon Valley to continue his work.

"The computer manufacturing industry in our country has virtually stopped. In fact, it is safe to say that it has ceased to exist."

The speaker is Boris Babaian, an affable 60-ish bear of a man with imposing black eyebrows whose face is unmistakably stamped with bold Slavic features. His imprint on Russian computer science—past, present, and future—is equally legible.

Babaian is one of the scientific stars of the former Soviet Union. He heads the computer division of the 60,000-employee Institute of Precision Mechanics and Computer Technology, a member Institute of the Russian Academy of Sciences, where he has worked for more than 30 years. His team there was responsible for developing the supercomputers that enabled the Soviets to become masters of nuclear weapons design and to become preeminent in space exploration. For their work in producing the Elbrus-2 computer (named after Mt. Elbrus in the Caucasus, highest in Europe), Babaian and some of his colleagues were awarded the coveted Lenin Prize in 1987. Babaian gained the sobriquet "the Seymour Cray of Russia," after the reclusive American genius who pioneered supercomputer design.

But now Babaian is wearing a second hat. He is chairman of the board of directors of the Moscow Center of SPARC Technology, which has branches throughout Russia. SPARC stands for "scalable processor architecture" and is a trademark of Sun Microsystems Computer Corp. of Mountainview, Calif. What is Babaian doing associating with Sun, a leading maker of desktop workstations using RISC (Reduced Instruction Set Computing) technology?

The answer is that Babaian, like many other scientists in the former Soviet Union, is finding salvation for his work and his colleagues through a commercial agreement with an American company willing to take some risks to capitalize on an enormous pool of talent.

The collapse of the Soviet Empire at the end of 1991 brought not only political turmoil but economic disruptions that threatened to break up Babaian's team at the Institute. When orders from the military-industrial complex for the El-

[Continued on page 68]

Computer legend Boris Babaian appears with a blowup of a Sun Microsystems chip design in the background.

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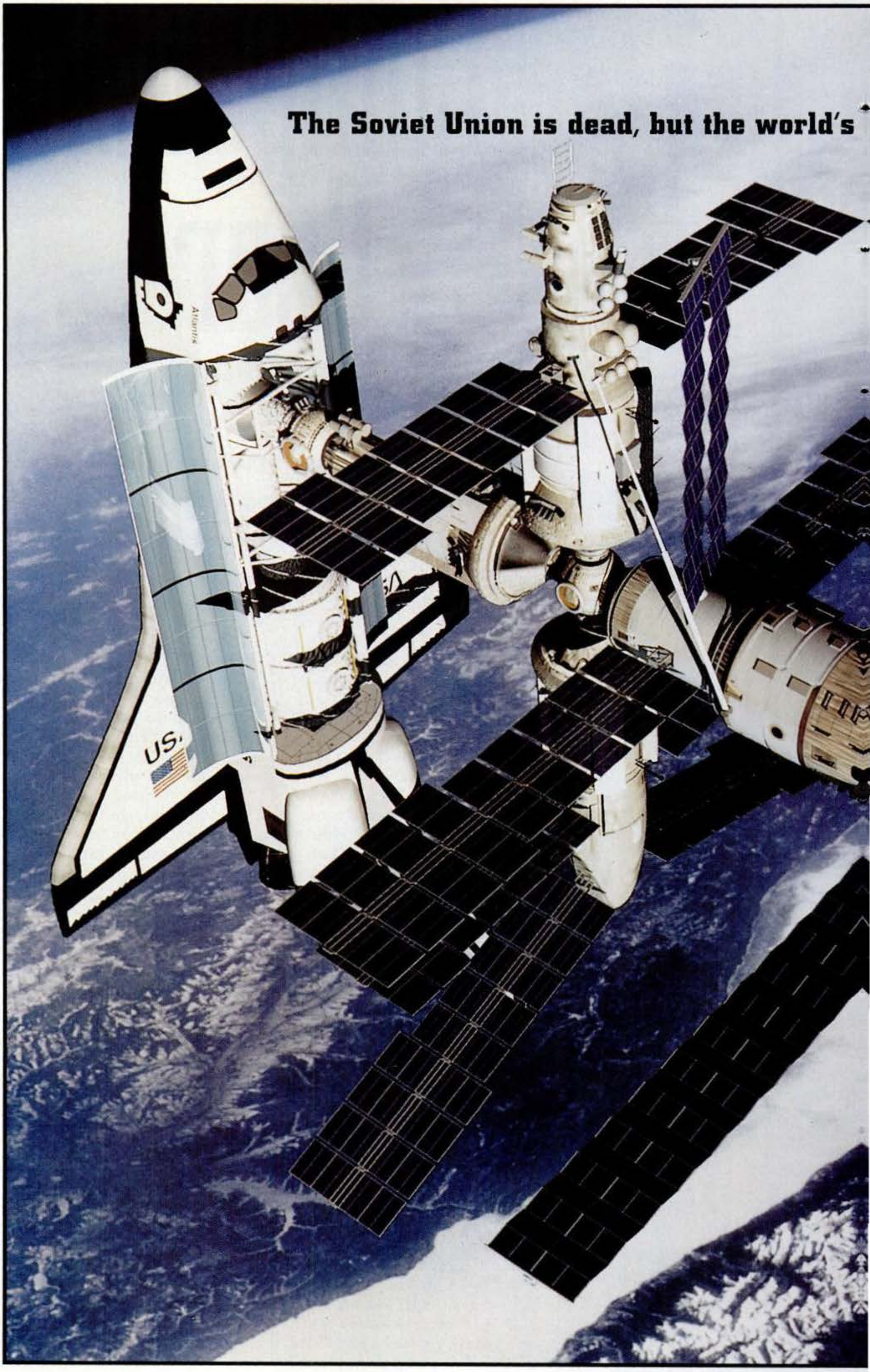
America's lone space station, *Skylab*, consisted of an empty third stage from a massive Saturn V moon rocket. The enormous cylinder measured 120 feet long, three times the length of Russia's *Salyut 1* station. Problems plagued *Skylab* from the moment it was launched in 1973. Temperatures inside the station hovered around 110°F, the shower leaked, and critical equipment needed constant repair. After three visits in 1973, *Skylab* was sealed shut in early 1974 and left to rot 275 miles above Earth. It fell from orbit and disintegrated in the atmosphere in 1979.



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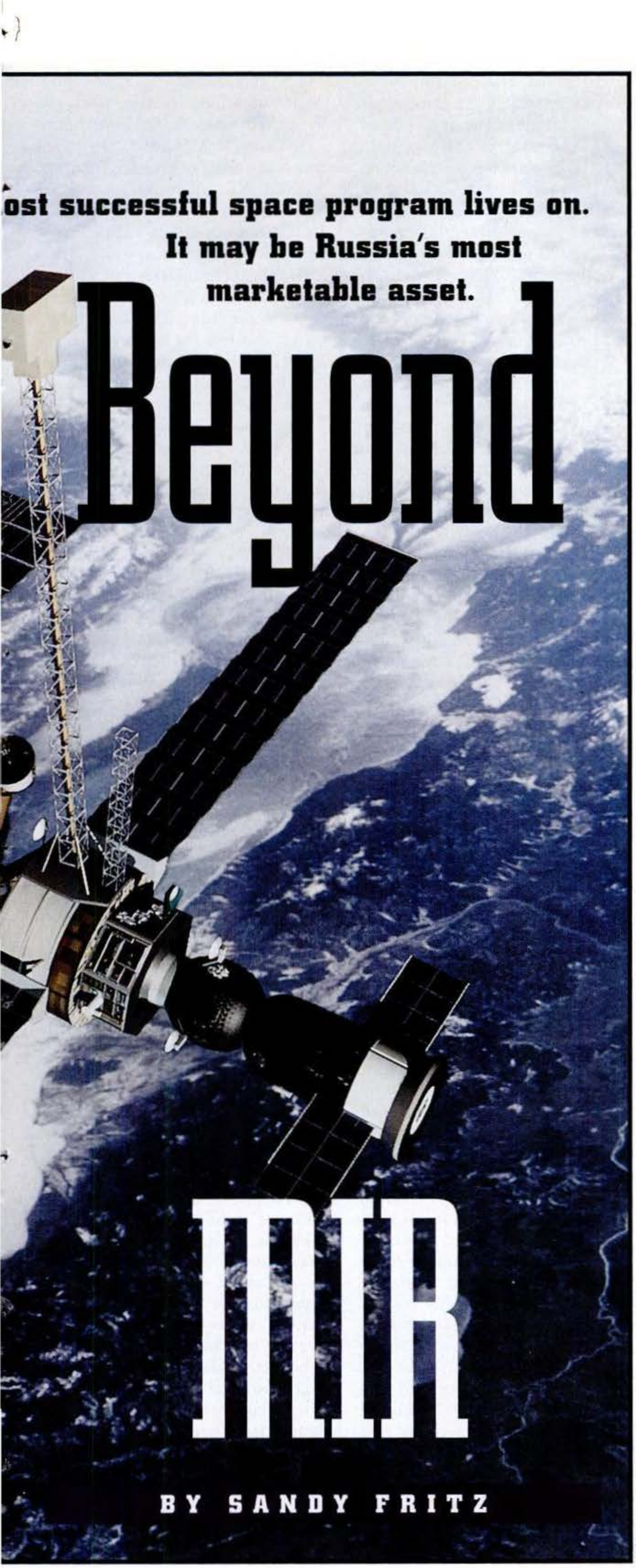
ost successful space program lives on. It may be Russia's most marketable asset.

Beyond



NASA

BY SANDY FRITZ

Soviet space scientists and cosmonauts were soldiers in a war. It was a war of firsts, biggests, and bests that raged above the planet, where victories were quickly surpassed by the opponent. And during the early days of the Cold War's space race, the Soviets beat the Americans in every key battle: first into space, first space walk, first multi-person crews, first rendezvous of two spacecraft.

Now the war is over. The cutthroat competition of the space race is gone, and in its place stands a new credo: Share the costs, share the risks, share the data. Myriad cooperative projects unimaginable a decade ago are now under way between the two former archrivals, including:

- The design and building of an international space station.
- The launching of American satellites on Russian rockets.
- Tentative agreements with NASA to explore the sun and Pluto.

Space, once the key battlefield of the Cold War, has become a proving ground for new openness and cooperation between the United States and Russia. And if any international effort to explore space is to succeed, it must rely on Russian know-how.

None doubt the potency of the technology developed by the former Soviet Union's space program. While the U. S. was struggling to build a rocket strong enough to get monkeys off the ground during the start-up of the Mercury program in 1959, the Soviets were already building boosters powerful enough to hurl satellites to the moon. They managed this feat three times between 1958 and 1960.

By the end of 1961, the U.S. had tallied one suborbital flight by Alan Shepard that lasted 15 minutes. That same year, Soviet cosmonaut Gherman Titov stayed aloft for 25 hours and 18 minutes. By the time John Glenn managed three orbits in 1962, the Soviets were rendezvousing spaceships above the planet. The following year, they sent a cosmonaut into orbit for nearly five days.

The ability to put humans and satellites into space remains one of Russia's key strengths. "The launch vehicles at their disposal are probably the most attractive

Vision of the future or pie-in-the-sky? Russia's *Mir* space station is shown linked to the U.S. shuttle in this artist's concept.

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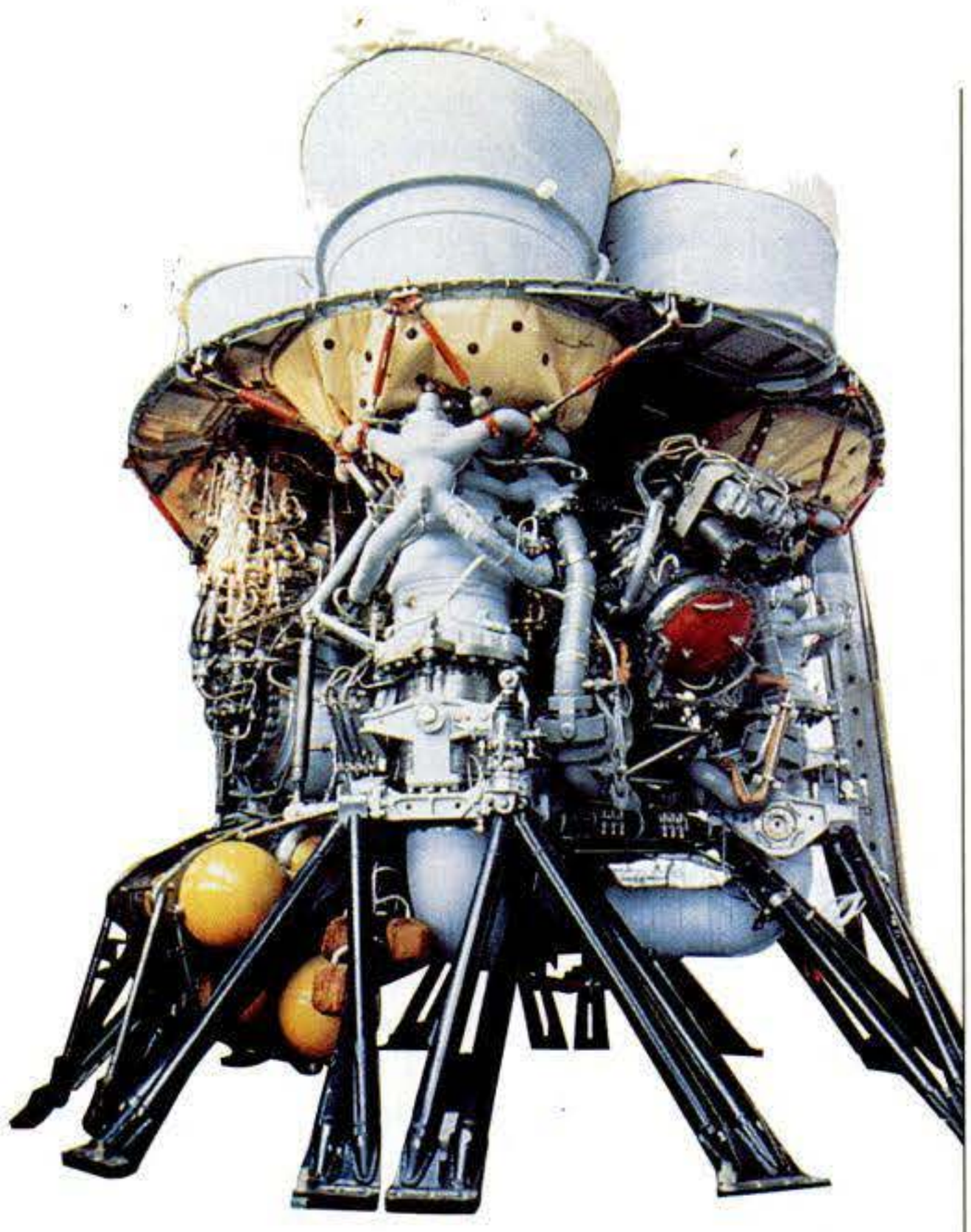

SOVFOTO

Motors from Russia's Energia rocket (above), renowned for their reliability, produce 6.6 million pounds of thrust. The 4.4-million-pound Energia launch vehicle (right) can carry three times more payload into orbit than the U.S. shuttle.

element for any kind of unified program," says Nick Johnson, an analyst with Colorado Springs-based Kaman Sciences, a chief contractor for the U.S. military's space surveillance systems. "Not only are these vehicles highly reliable, but they have many different types of boosters that span payload capacity from less than one to over 20 metric tons. Depending upon what kind of spacecraft you have and what kind of orbit you want, they've got a launch vehicle well suited to the mission."

Johnson credits methodical development for the Russians' success. "Most of their launch vehicles have been flying for 25 or 30 years," he says. "These are classic, tried-and-true designs, so accidents are rare." A ten-degree drop in temperature or a mist at Cape Canaveral can scrub a shuttle mission, but the Russians can launch missions in *any* weather. "They think nothing of sending up a satellite in temperatures of 30 degrees below zero," says Johnson. "They can launch in very high winds, and I've even seen videos of a launch in the middle of a blizzard."

Perhaps the most valuable jewel in the crown of Russian space achievement derives from their space stations and the data they have accumulated on the effects of microgravity on the human body. "NASA is almost a newcomer to space stations," says Roald Sagdeev, a Russian physicist who is now a distinguished professor at the University of Maryland. "NASA's experience with long-duration flight from Apollo expired long ago. But the Russians have managed to keep men in space constantly for two decades."

The Soviets may have lost the race to the moon in 1969, but when they did, they simply changed the game. Space stations became their new goal. Their first station, *Salyut 1*, took only 18 months to design, build, and launch. As *Salyut* went though six successive generations between 1971 and 1986, the United States again played catch-up. *Skylab*, launched in 1973, fell from orbit in 1979 after just three changes in crew. The 84-day flight record established by American astronauts in 1974 was surpassed by the Russians three years later in the ordinary course of their space station evolution.

By the time *Salyut 7* was launched in 1982, the Soviets had developed robot supply ships, sophisticated docking nodes for linking incoming ships and additional living modules, and escape vehicles for cosmonauts on board. *Mir*, launched in 1986, incorporated everything the Russians had learned from 15 years of experience and has remained continually occupied ever since.

The Russians have amassed vast databases detailing what happens to humans when they live in a near zero-gravity environment for long periods. Says Kaman's Johnson: "The Russians' physiological and psychological database [on the effects of long-term space flight] is without peer. They've also done very good work in terms of creating nearly closed life-support systems aboard their stations."

When humans go into space, their legs become spindly and their chests and faces puff up because, without gravity, blood collects in the torso. This forces the heart to work far harder than it does on earth. In addition, muscles begin to shrivel, and the human skeleton decays. Early long-duration space flights left astronauts and cosmonauts unable to walk or even stand when they first returned to earth.

Although they have yet to reveal all of their research, the Russians do acknowledge that a rigorous exercise regimen while in space is absolutely essential. About a month before returning to earth, *Mir* inhabitants exercise for about six hours a day to prepare for the strain of gravity. When *Mir* cosmonauts Anatoly Solouyev and Alexander Balandin were unable to exercise during the final month of their stay because they spent so much time outside the station repairing their *Soyuz* return capsule, they returned home in pitiful shape. A film of the cosmonauts being retrieved from their reentry vehicle revealed two pale men, laboring to breathe and unable even to lift their arms.

Excellent launch vehicles, experience in space station housekeeping, and a proven health regimen: these are the chips the Russians bring to the negotiating table. America and Russia have good reason to pool their chips. With the Cold War gone, both space programs must find new reasons to justify their existence. "If I were Clinton or Yeltsin," ponders John Pike, the director of space policy for the Federation of American Scientists, "and I wanted to find the most visible undertaking that would unite both powers, it would be the space program. The space race was such a defining feature of the Cold War that to be cooperating rather than competing sends a real clear message to the world."

In December 1993, Russia and the U.S. sent that message by formally agreeing to join their space station efforts. The program, if approved by the U.S.

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Congress, calls for three phases. During the first, the American space shuttle would link with *Mir* at least ten times from 1995 through 1997. The shuttle would ferry upgraded solar arrays to the Russian station, and American astronauts would make extended stays. To accommodate the Americans, the Russians would add new modules to *Mir* to house Russian and American scientific experiments. The U.S. will pay $400 million over the next four years to support these *Mir* missions.

Phase two begins in 1997, with joint Russian/American launches of the basic building blocks for the new space station; Russian-made boosters would muscle the main pieces into space. By the end of 1997—an estimated 90 launches later—the core station would be ready for inhabitants. A *Soyuz* Assured Crew Return Vehicle would be added in 1998.

Cramped quarters in *Mir* have sustained cosmonauts for more than a decade.

After the U.S. and Russia have established the station, phase three begins in 1999, with module labs from Japan, Europe, and Canada fleshing out the structure. Under this timetable, the station would be ready for permanent occupancy by a crew of six in the year 2001.

The plan is ambitious and daring. But the number of potential stumbling blocks is enormous, the foremost being Russia's current instability. When the Soviet Union broke up, for example, Russia didn't even know where it would launch its *Soyuz* missions; Russia's key launch site for manned spaceflight, the Baikonur Cosmodrome, suddenly found itself inside the newly independent state of Kazakhstan. Only recently did the Russians negotiate a long-term lease for the site. And the well-known economic hardships that have shaken the superpower have affected the space program as well, leaving many wondering if Russia will be able to afford any space ventures.

At the height of its space program, the Soviet Union hosted 160 launches a year, versus about 100 for the United States. Since the dissolution of the USSR, Russia has maintained a vigorous pace, launching over 220 missions, more than the rest of the world combined. Still, that number is sure to drop.

Government-sponsored space science missions are the first to feel the pinch. "The Russian space program is still in a fluid state," says analyst Johnson. "Although the major programs remain underway, they are becoming increasingly delayed." He cites the recently launched *Cronos I*, designed to observe the sun during its 11-year cycle of waxing and waning.

"That particular spacecraft," says Johnson, "was supposed to be launched several years ago to monitor the sun during solar maximum. Unfortunately, delays put it in the cycle where we're rapidly approaching solar minimum. If they're very lucky, the craft might last until the next maximum to do what it's designed to do. But it's a long shot."

Plans to send a probe to Mars have also been delayed. Mars 94—originally Mars 88, Mars

SOVFOTO

HIGH JUMPING

Yuri Gagarin was the first man in space, but he did not land with his spaceship. In fact, none of the five Russians who flew *Vostok* missions between 1961 and 1963 landed with their ships.

To adequately protect the cosmonauts from the searing heat of reentry, an asbestos outer shell and a parachute were added to the *Vostok* spacecraft, which made it too heavy to land safely with a passenger on board. The flight plan required cosmonauts to eject from the plummeting craft 4.5 miles above the ground, when the ship had slowed to about 500 feet per second. Perhaps it was Valentina Tereshkova's experience as a skydiver that prompted the space bureau to choose her as the first woman in space.

Had the Soviets admitted that ships and cosmonauts landed separately, they would have technically lost the honor of being the first nation to put a man into space. The Federation Aeronautique Internationale required that both man and capsule land together in order to qualify as a valid record. Since no proof could be found that the Soviet cosmonauts did not land with their ships, they were awarded the honor.—*S. F.*

SOVFOTO

The first woman in space used her skydiving skills to return to earth.

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90, and then Mars 92—has been rescheduled for 1996, casting an ill light on Russia's ability to deliver the goods on time. The European space community, which developed many of the experiments and instruments for the mission, is especially annoyed. Follow-up probe Mars 96, which would put a balloon in the planet's atmosphere and a rover on the surface, has been rescheduled for 1998.

And it appears that Russian rocket manufacturers can't even deliver on time for their government's own space efforts. Last year, a manufacturer failed to deliver motors for a *Soyuz* rocket, leaving three cosmonauts marooned aboard *Mir* two months longer than planned.

Despite the delays and problems that abound in the newly formed country's space exploration projects, the future looks bright for the manufacturers of Russian space hardware. "It's very hard to conceive of the entire Russian space program falling apart," says Johnson. "Their need for communications satellites, defense satellites, and navigation satellites is very, very strong. And all of those programs, by and large, are being maintained at their former operational levels."

Also on Russia's side: reduced launch costs. "Expenses are much lower," notes Johnson. "On top of that, all the research and development has already been done, and their launch vehicles are in mass production."

"Things are beginning to calm down," says physicist Roald Sagdeev. "The Russians accept that the size of their space program is shrinking, and they are trying to define what could constitute the survival minimum. They realize they have only a few assets to bring to the marketplace, and space technology is one big asset."

The Russians are already beginning to market their space technology. Their sturdy launch vehicles, the envy of the world, have caught the eye of several American rocket manufacturers. Martin Marietta, for example, is proposing a new launch vehicle that uses the first stage of the massive Russian Zenith rocket to put a 20,000-pound payload into near Earth-orbit. Aerojet Aerospace, another rocket manufacturer, recently imported a heavy-duty Russian NK-33 engine for inspection as a possible replacement for the lower-thrust, less-efficient American engines in its Delta and Atlas launchers.

The recent fusion between a branch of U.S.-based Lockheed Aerospace and two Russian rocket manufacturers, Khrunichev State Research and NBO Energia, has given birth to an entity with powerful commercial potential. Lockheed-Khrunichev-Energia International's (LKEI) sole commodity is the Proton launch vehicle, the most reliable rocket ever to fly. The fledgling effort already has captured $600 million worth of accounts with satellite-makers such as Hughes Aerospace, Martin Marietta, and Loral. And nearly one-third of Motorola's 66-satellite Iridium system, designed to provide global wireless telecommunications services, will head into space aboard LKEI's Proton rocket.

LKEI president Charles Lloyd is optimistic about the future but is also cautious. "Proton has not yet launched a Western-manufactured satellite," he warns. "There are some technical challenges ahead. The engineering methods are somewhat different in Russia. But I don't see anything that can't be overcome."

The Russians remain free to pursue their own sales efforts, and the Khrunichev bureau has already scored two solo hits: one launch with Inmarsat, a 67-nation telecommunications consortium, and another with a European satellite television company. Other Russian space technology companies are forging bonds with the West: Satellite-maker Loral wants light-

STRANGE CREW

Throughout its long space station missions, the Soviet Union has hosted visitors from many nations, including Mongolia, Vietnam, Cuba, and Japan. But so infectious was the joie de vivre of Frenchman Jean-Loup Chretien that he was the only guest cosmonaut invited aboard both *Salyut 7* and *Mir*.

Chretien delighted in the kind of tomfoolery that spiced the humdrum of daily routine. Anatoly Berezovy, a cosmonaut aboard *Salyut 7* for seven months in 1982, recalls in his journal a prank Chretien played during his eight-day stay: "He brought a monster mask, and yesterday when I was working, I went behind a panel and this shaggy, horrible face came out of the scientific equipment compartment. I was startled and screamed."

During his *Mir* flight, Chretien brought his own cuisine and played chef/waiter for the crew. Cosmonauts feasted on delicacies, including compote of pigeon with dates and dried raisins, duck with artichokes, oxtail fondue with tomatoes and pickles, beef bourguignonne, sautéed veal marengo, ham and fruit patés, cheeses, nuts, and chocolate bars. Meals were accompanied by music from a hand-cranked organ Chretien brought along to provide the right atmosphere. His only regret: that wine could not be served with his national cuisine.

"The food was OK, but a little heavy for space," recalls Sergei Kirkalev, who spent 25 days with the Frenchman. "It was good to get back to plain black bread after he left."—*S. F.*

SOVFOTO

Premeditated goofiness: Frenchman Jean-Loup Chretien (far right) shocked his comrades during the *Salyut 7* mission.

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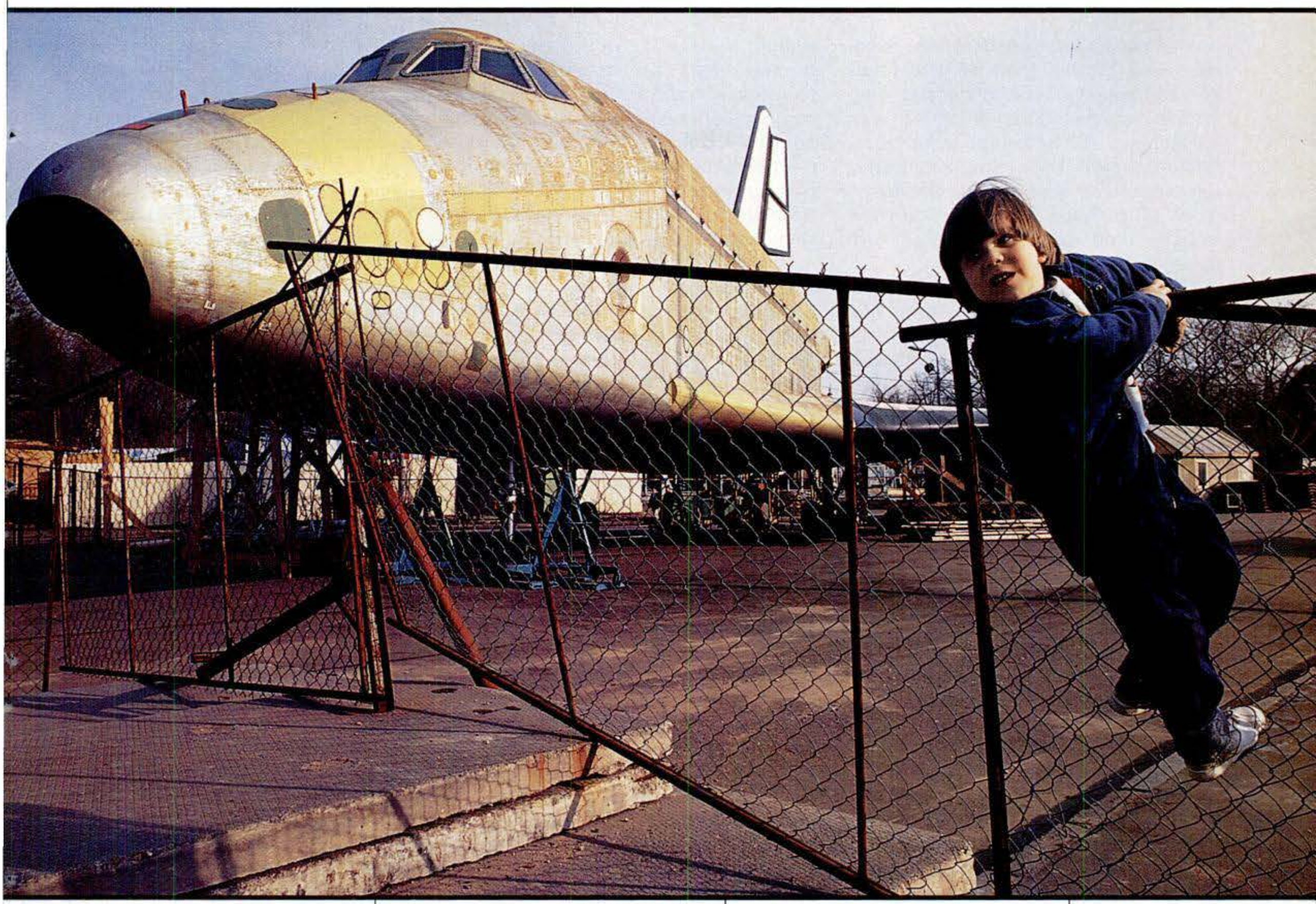

VLADIMIR VIATKIN

weight thrusters made by the Russians, and Rimsat, an American telecommunications company, wants to buy Russian satellites. Boeing Aerospace was so pleased with the service and results of a recent crystal-growing experiment on *Mir* that it is planning to purchase more time on the space station.

Joint ventures involving scientific satellites also seem promising. While the Russians forté is launch vehicles, the sensors and scientific hardware in their satellites lack finesse. "On the average," says Johnson, "Russian scientific gear is about ten years behind the West."

A recent effort between the U.S. and Russia blends the strengths of both countries: A Russian polar-orbiting satellite, fitted with state-of-the-art American hardware, successfully mapped ozone depletion in Antarctica. In the same spirit, the Americans would like to piggyback a small rover on Russia's Mars '96 flight. The Russians have made room and have accepted an American manipulator arm and computer for their own rover.

NASA seems eager to join hands with the Russians. This March, a NASA delegation visited Russia to discuss joint missions to explore the solar system. "We're looking at how we can initiate cooperative activities," says NASA's Bill Piotowski. "We're looking at the missions both countries are planning and asking if there are some things we can do together."

The visit yielded ideas for an exciting pair of missions, tentatively named Fire and Ice. Ice calls for a Russian Proton launch vehicle to hoist an American spacecraft on its way to Pluto. A small Russian probe would deploy from the craft in the vicinity of the ninth planet to determine its chemical composition and landforms.

The Fire mission would send a satellite hurtling into the sun. Like Ice, a Russian booster would propel an American spacecraft into orbit inside Mercury, and a small Russian probe would drop into the sun. "No spacecraft has gone that close before," says Piotowski. "It would gather measurements of the sun's magnetic field, the particle environment, solar flares, all of the phenomena associated with the sun."

The Soviet Union's estrangement from the West has been a defining feature of the 20th century. Russia and America now stand at a brink where they can use their space programs to forge a new form of cooperation. "The 21st century is undoubtedly going to be better than the 20th, simply because Moscow has moved out of the problem column and into the solution column," says John Pike. "Cooperation in space can serve as a pathfinder to define all of the different institutional, organizational, cultural, and psychological differences and complements that would exist in all partnerships between Russia and the West. That kind of reason alone makes me optimistic that, no matter what problems come up, we'll be able to deal with them." PS

The *Buran* space shuttle flew only once into space, on automatic pilot. It now sits in the former Gorky Park in Moscow as a tourist attraction and concession stand.

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Computer Czar

[Continued from page 61]

brus-2 and its software dried up, Babaian found himself short of both funds and equipment. Work on the next-generation supercomputer, Elbrus-3, simply stopped. The inroads of galloping inflation meant that many computer scientists, who were earning the equivalent of perhaps 15 or 20 dollars a month, could not afford to stay with their jobs.

"Two or three years ago," Babaian told me, "there were something like 2,500 people in my division of the Institute, and now there are something like 1,000. The others were not fired. They left for better-paying jobs, changed professions. One man, a good programmer, left to program sewing machines that sew blue jeans together. Another is selling cigarettes. And many went to banks."

To save his enterprise, Babaian turned to the West...to Sun. He is now in charge of a hundred or so researchers in computer hardware and software employed by the Moscow Center of SPARC Technology (some 60 of whom also work for the Institute). The Center is an independent entity established in the spring of 1992. It is not owned by Sun, but it is funded by Sun and supplied with hardware—every engineer has a Sun workstation.

"If not for this arrangement," Babaian says, "in two years' time our team at the Institute would have been destroyed."

"What we do," says David Ditzel, director of Sun's SPARC Laboratories, who sat in on my interview with Babaian, "is contract with the Moscow Center as a separate firm. We've found that to be a very good mechanism for doing business in Russia. In some sense, this was an export control issue. This has been a very special project viewed cautiously by both governments."

What does Sun get out of this arrangement, and why did the company seek to go abroad for computer talent?

One answer, one that Sun and other U.S. companies in similar situations would prefer not to emphasize, is the ability to obtain very high-quality performance at minimal cost. Neither Babaian nor Sun representatives are willing to detail the financial arrangements. But the salaries of the Moscow Center employees, while, undoubtedly, considerably less than what such talent would cost in the United States, are certainly far more than the typical Russian salary.

"I can tell you," says Babaian, "that the people working with the Sun Moscow Center feel themselves quite well-off in our country."

Just what is Sun buying? Russian computer software designers are extremely adept at microprocessor architecture and basic algorithms. This Russian capability is in some respects more advanced than that of their Western counterparts, ironically because of the Russians' need to surmount the limitations of relatively less developed hardware, especially chip technology.

"We have a very difficult situation," says Babaian, "because our chip technology is very bad, totally noncompetitive. Until a few years ago, all of our production was used inside the Soviet Union, where it didn't have to face any competition. But with the change to a market economy, we had no chance. One of the main drawbacks of our previous history was that we tried to work in isolation. Nevertheless, many activities are continuing in my country."

Babaian cited the work of the Paragraph International team, founded by Stepan Pachikov, which developed the cursive handwriting recognition software that is used in Apple's Newton (first of a new generation of hand-held "personal digital assistants"). In 1989, Pachikov organized a Russian-American joint venture company that was self-financing and independent of either government, visited the United States, and signed a licensing agreement with Apple. The same team has signed a contract with Corel Corp. to incorporate its optical character-recognition software, called CuneiForm (named after the oldest known form of writing, current in Babylon circa 3,000 B.C.) into CorelDraw, a graphics program.

For years, Babaian says, there were two kinds of computer industries in Russia: one that did innovative work on its own computer designs, and the other that was forced by the government to copy Western designs. "But when the computers they had copied began to be imported at much higher quality, these designers were lost; they had lost their ability to innovate."

Babaian's past efforts were concentrated on high-performance computing, a continuation of the push to develop electronic digital computers begun just after World War II in Kiev by Sergei Lebedev, who founded Babaian's Institute. By the early 1980s, this effort had succeeded in producing machines capable of meeting the heavy computational demands of the Soviet space and weapons programs, although much of Soviet science had to rely on less than state-of-the-art systems, including copies of IBM mainframes and the workhorse Russian BESM-6 model, developed in the mid-1960s. That machine was rated at one mips (million instructions per second), close to global state of the art when it was introduced. But by 1991, high-level Soviet computers were lagging far behind those designed by Cray Research in the United States. The Elbrus-2, designed by Babaian's team and introduced in 1985, had a shared-memory multiprocessor architecture and was rated at 94 megaflops. (Supercomputers are generally rated in floating point operations per second—or flops—not instructions per second, because one instruction can result in as many as 64 operations, or calculations.) But in 1992, with the influx of more powerful computers from abroad, the production of the Elbrus-2 was dropped.

"When we started this project," says Ditzel, "you needed an export license to ship any computer faster than 12.5 million operations per second. That ruled out some Macintoshes, Pentium PCs, lots of PCs. So a lot of irrational things were going on. At the same time the regulations were hurting American companies, the Russians were importing computers with exactly the same performance from Taiwan or Korea and other places. So we weren't stemming the flow of sensitive technology at all. I think that's why the U.S government finally revised the export regulations.

"Now the limit is 1,000 million operations per second. You can export freely up to that level, and for anything beyond you just need an export license. So you could export a Cray to Russia if you obtained the license." Sun Microsystems has shipped more than 1,000 SPARC-based workstations to the former republics of the Soviet Union.

Babaian's designs for computer architecture have always relied heavily on parallel processing: using multiple processors to attack different tasks simultaneously, rather than processing one task at a time and then forwarding the result through a straight-line sequence of operations, the latter an architecture called serial, or von Neumann, after the great German-American computer genius. When I asked Babaian about this, he was dismissive: "I do not like this von Neumann or not von Neumann usage. Different people assign different meanings to these words. Let's just say that the Elbrus computers are to a great degree parallel, especially Elbrus-3. It has parallelism at the processor level, and inside the processor at the instructional level."

When Babaian and some of his colleagues received the Lenin Prize from Mikhail Gorbachev for having produced the first Soviet supercomputer, the Elbrus-2, the accolades generated some acrimony inside certain quarters of the scientific establishment, who believed

that Gorbachev had been hoodwinked. When I asked Babaian about this, he shrugged and said: "First of all, there is really no definition of what a supercomputer is, just that it is the most powerful at the time. And it is absolutely true that the most powerful computer in Russia is the Elbrus. Maybe it's not a real supercomputer, just our fastest. It's not really necessary to decide."

Babaian and his team are now working on Elbrus-3, a prototype of a shared-memory machine with 16 processors that would have a theoretical peak performance of almost nine gigaflops, ten times that of Elbrus-2.

"The big difference between this machine and those in the West," says Babaian, "is that we are using chips with a thousand gates per chip, and Western chip technology has achieved more than a million gates per chip. This is a big handicap."

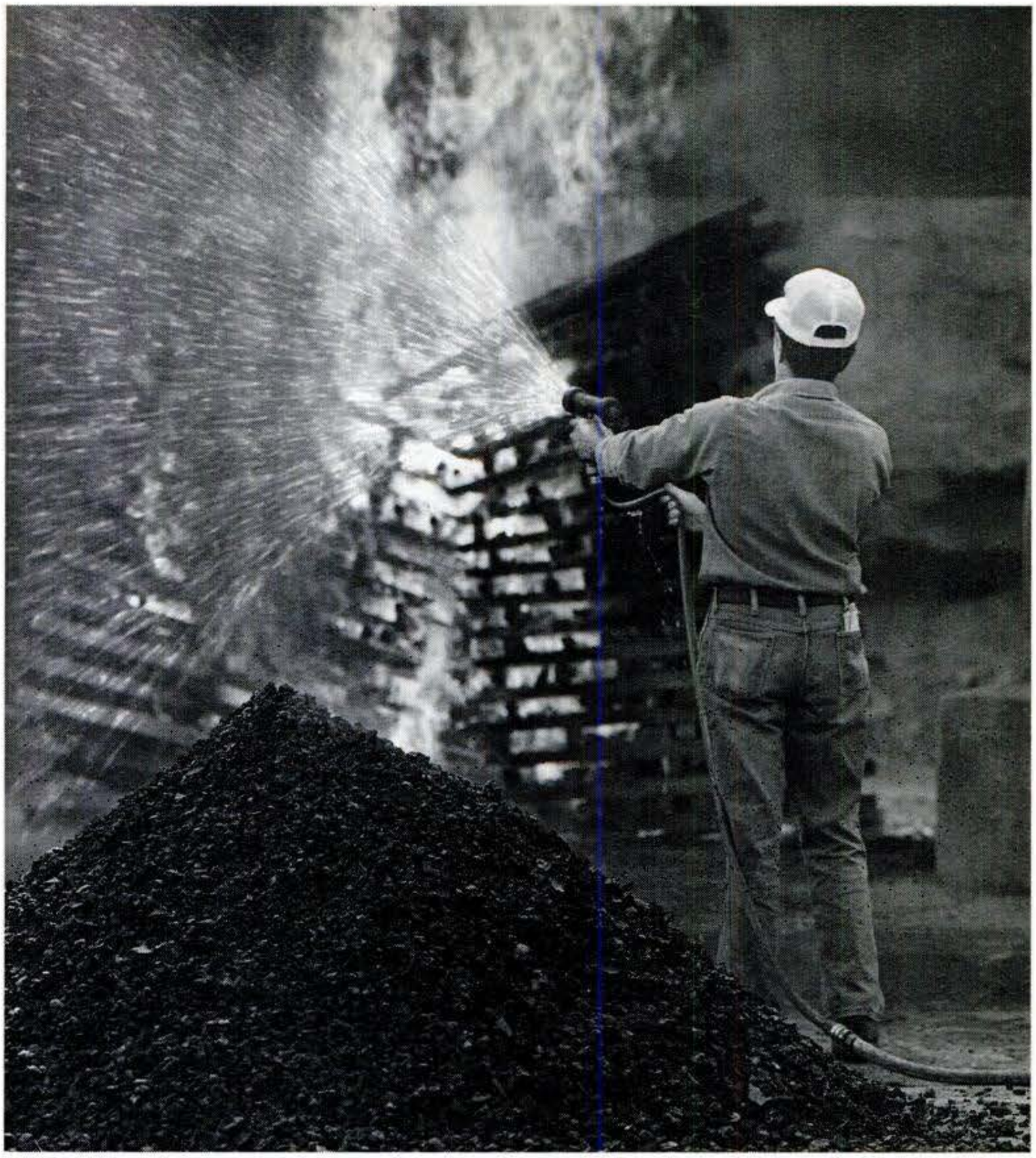
Ditzel adds, "The fact that Babaian has been able to achieve a theoretical performance better than some of Cray's current machines with technology that far behind is a great tribute to the intellectual power behind these computers' architecture."

Babaian explains that one source of this high speed is the logical organization of the computer, which takes full advantage of the parallelism existing in algorithms—the instructions the computer must follow. Simultaneously, his team has developed matching software technology. Doing these two things together is the key, he says.

"The project Sun is doing jointly with Babaian and his team is to figure out how to apply to Sun's SPARC architecture these techniques that have been learned independently. The aim is to build a kind of supercomputer-influenced microprocessor to make SPARC programs run very fast. They are generating the logical techniques, and Sun is supplying the team to do the physical implementation in VLSI [Very Large Scale Integration] chip technology. Boris is helping us understand what to build and how to exploit more parallelism, and then we're combining that with our expertise in implementing the concept in hardware expeditiously.

"The result of this collaboration could be Sun workstations ten times more powerful than the workstations that we are shipping today."

Babaian concluded confidently: "There is no question that the computer sector in Russia will definitely be restarted—but only on the basis of international cooperation. It is good that such cooperation is also in the interests of the United States." PS



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Lifestyles of the Not-So-Rich

[*Continued from page 44*]

Russia was always able to catch up with the latest technological achievements, but they never reached people's homes. Now that the free market has arrived with a bang, that has not changed for the better. In fact, it is getting worse. Goods are coming, but not from Russian factories.

At the end of March 1994, the Russian State Statistics Committee released production figures covering the two previous months. Compared to 1993, 54 percent fewer vacuum cleaners had been manufactured; 42 percent fewer washing machines; and 25 percent fewer tape recorders.

It is hard to say how accurate these fragmentary statistics might be. During 75 years under communism, the Soviets developed great skill in fooling themselves with an abundance of goods on paper, while store shelves remained empty.

Over the years, Russians did manage to produce large numbers of two major appliances: refrigerators and televisions.

Thanks to the climate, Russians in rural areas still use the most reliable and environmentally correct ways to store food. In the winter, they stick bags out of the window. In a small city in Russia, one can see these food bags hanging from every apartment window. In the summer, food is stored in a special cellar.

But in large cities, most residents have refrigerators. The most popular brand is the Morozko, or "Father Frost," named after a Santa Claus-like character from a fairy tale. Because an average Russian apartment is so small, the refrigerator is just about big enough to accommodate a bottle of vodka or buttermilk, a piece of sausage, and a pot of borsht. Forget about ice-makers and self-defrosting.

The real problem for the Russian economy now is that domestically manufactured goods are being replaced by foreign ones. These are cheaper, more reliable, and nicer to look at. It has long been clear that few Russian goods can compete on the world market. Now it appears that they can't even compete on the domestic market. Even Russian-made TVs are being replaced by Korean sets.

Every Russian household has a TV, or "blue box," sitting in the "red corner" (the word "red" in Russian also means "beautiful"), the best place in the house. Television is more than entertainment in Russia. It is a way of life. The TV was always the major purchase of the Russian family. Money was saved for years to buy a better brand. I remember endless kitchen-table discussions over which brand was better, "Horizont" or "Elektronika," although both were pretty primitive.

There are only four state-owned TV channels serving the whole country. A lot of independent television companies have emerged in recent years, but Russian sets can receive only eight channels, which makes life difficult for the new TV stations.

But that may change within the next five years as foreign models replace Russian ones. Korean models are the most popular now, but a rich Russian will certainly own a Sony Trinitron and a Panasonic VCR.

There is no market for American brands, because Russia uses the French television transmission standard rather than the American system. The Koreans and Japanese manufacture multisystem TVs and VCRs and have taken over the Russian market.

Every city in the former Soviet Union has an identical building. If you were suddenly deposited in front of one of these buildings, it would be impossible to know which city or even which republic you were visiting. The building occupies the choicest location in the city, on a central square. It is a monumental structure of glass and cement with a vast entryway, designed to make the visitor feel tiny and useless. In the middle of the square, amid trees and flowers, once sat a statue of Lenin. The building is the former regional headquarters of the Communist Party. This style is called "Stalin's empire." It is the architecture of totalitarianism.

Now that the communist empire has broken down, these buildings belong to city governments. The statue of Lenin has probably been knocked down and carted away. The line of chauffeured limousines in the driveway may have thinned out. But the humiliating architecture remains. I still feel uncomfortable visiting city bureaucrats.

From the late 1920s to the mid-1930s—after the Bolsheviks came to power and before Stalin put an end to avant-garde experiments—there was a burst of "constructivism." What remain are a few buildings in Moscow shaped like a ship or a wing. Some ideas of the time were to build the Ministry of Agriculture in the shape of a corn cob or the Ministry of Metallurgy in the shape of a blast furnace.

One of the more amazing leftovers of that era is an apartment building in Moscow designed for actors, writers, and artists. The apartments were built without kitchens. The architects of the young republic of socialism, designing a new approach to human life, thought that creative people should not cook for themselves. Each apartment was equipped with a dumb waiter connected to a restaurant below. Tenants were supposed to send down their orders and take direct delivery of tasty meals. It never worked.

Then came Stalin, whose love of enormous buildings set the style for dictators ever after. He built the first skyscrapers in Moscow—strange mixtures of Gothic, Baroque, and pure Stalin.

Stalin was obsessed with the idea of building the tallest building in the world, the "Palace of Soviets," which was to be topped with a giant statue of Lenin. You can imagine the size of this building: The architect planned to build a library inside Lenin's head. But the project was never realized.

When Khrushchev came to power, he, too, entered history with a totally new idea for the Soviet construction industry. In the beginning of the 1950s, people in cities mostly lived in communal apartments. Old buildings with spacious living quarters were subdivided into as many as 20 units per apartment, with everyone sharing kitchen and bathroom facilities. (The toilets were hardly ever usable, because tenants could never agree whose turn it was to clean them.) People would give anything for the right to private space, separate from unwanted neighbors.

Khrushchev ordered a new kind of building: five stories, no elevators, apartments the size of bird cages. The first area where these houses were built was the Moscow district called Cheremushki. Every city in Russia has a district of these five-story buildings, officially named Cheremushki. But residents have another word for these districts. The word for *slum* is *trushchoba*. Russians combine that with the name of their benefactor and call the buildings *khrushchoba*.

It was a great thing for people to finally get some privacy. But there were never enough buildings. An apartment of your own is still the great Russian dream.

It is hard to identify any contemporary Russian architecture, especially when building methods are so archaic. Russian construction is more like tailoring than fitting puzzle pieces: This panel is too large, so we should cut it. That wall is too low, let's add some bricks. As soon as Russians move into a new apartment, they begin replacing everything—the wallpaper because it is ugly, the toilet because it doesn't work.

A common landmark in Russia is the unfinished construction project. The Soviet Union was a country of campaigns. Russians love to start big things—the biggest power station, the biggest nuclear plant, the biggest canal. What they do not like to do is finish. Thousands of half-built houses, factories,

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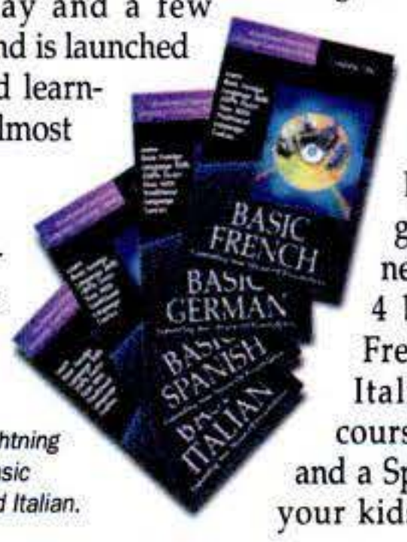

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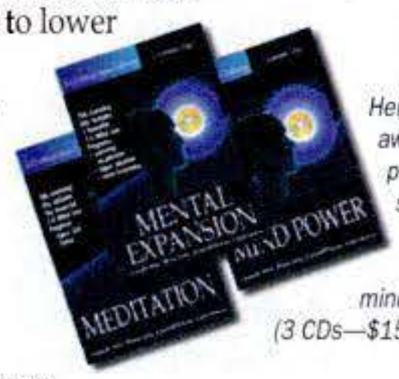

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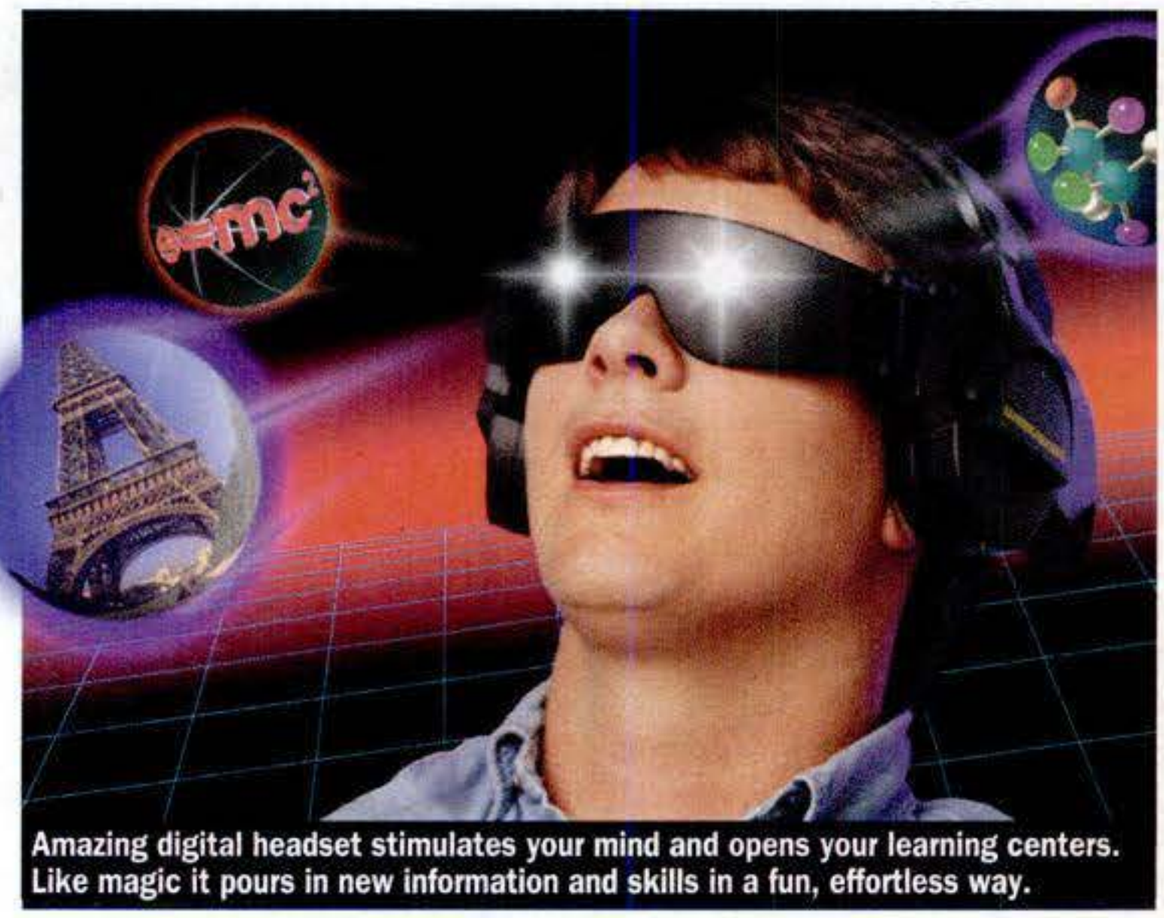

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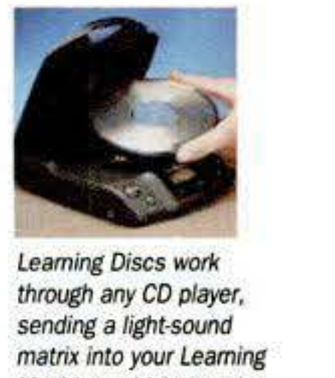

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Lifestyles of the Not-So-Rich

[Continued from page 71]

kindergartens, restaurants, and schools are scattered from Kamchatka to Kaliningrad. Maybe these ugly, rusted skeletons are the ultimate expression of modern Russian architecture.

But there are some encouraging signs, particularly in big cities. Moscow now has a new office building on Tverskaya Street, next to Red Square. Although the building is ordinary by Western standards, in Moscow its tinted windows and clean lines are eye-catching. It has the most expensive office space in the city.

Village architecture is something altogether different, of course. Many of the wooden houses have a certain charm, but the clearest symbol of rural life is the ever-present outhouse.

Russians like to quote their great 19th century writer, Nikolay Gogol: "There is not a Russian who does not like a fast ride." Gogol was referring to horses, but no matter. Russians love fast, reckless driving, whatever the conveyance.

The same author has another saying that is not quoted so often: "There are only two things that could destroy Russia: fools and the lack of roads."

Transportation in Russia is a nightmare. There is no infrastructure for traveling, although the whole country has been in constant movement from one place to the other. Stalin not only split up families, he even shuffled whole nations. He moved millions of Crimean Tartars to Uzbekistan and Volga Germans to Kazakhstan.

If you are driving a car, there will be no Roy Rogers or McDonald's on the road. Gas pumps to fill your car will be extremely rare. Do not dream about motels or campsites, AAA or emergency road calls—such things do not exist. Freeways and highways are foreign words that make no sense at all in the Russian language. Roads are undivided—one of the most common kinds of accident is a head-on collision. Holes and bumps are so common that drivers do not consider them obstacles. As long as there is any pavement at all, they will keep driving. Many villages are accessible only by tractors in the spring, when everything is drowning in mud.

Russians do not travel far by car. Gasoline costs about $2.50 per gallon, and road trips have become even more dangerous with the appearance of car-jackers who steal cars and leave the owners on the road. Trucks unguarded by armed escorts are often robbed. Recently, the Ministry of Internal Affairs issued an order telling drivers not to stop even for uniformed officers, unless they are stationed at a roadside police kiosk. The men in uniform could be robbers.

Trains are slow and dirty. Beware of romantic stories about the Trans-Siberian Railway or other long train excursions. It takes two weeks to cross the country from west to east. A separate compartment is absolutely necessary; otherwise you will be stuffed into a car with 80 people (and two uncleaned toilets).

The best transportation in Russia is by plane. I can testify to this because I worked as a reporter for a daily newspaper for 12 years and had to travel for nine months of the year.

Despite plenty of horror stories, Aeroflot has not made the *Guinness Book of World Records* in catastrophes.

If a flight is longer than three hours, the passenger receives a cup of liquid remotely resembling coffee and some boiled chicken—hence the nickname "chicken Aeroflot." This is the only service available.

Now some private competitors are appearing. The cost of tickets for these "commercial flights" is unbelievably high. But a passenger who wants to do so can get loaded on vodka, and the flight attendants sometimes smile at passengers instead of yelling at them.

The worst thing about Aeroflot is not the flight but the check-in. One has to stand in line for hours to buy tickets, because there are no travel agencies and tickets are not delivered. After your ticket is checked, you are herded into a minuscule room called an "accumulator," to await boarding. I have seen elderly people faint in these rooms in the summer.

Many Russians are afraid of flying and prefer trains. Others joke about that, saying traveling by train can be almost as dangerous—after all, a plane could always fall on top of the train.

An elderly Henry Ford, the story goes, paid a visit to an automobile factory in Moscow. He was being shown the production line when suddenly he began to cry. "What's the matter?" asked the manager. "I was just taken back to my childhood," Ford replied.

It is impossible to fit antipollution devices on vehicles driven in Russia: The quality of the gasoline is so bad that the fuel would destroy the catalytic converters. In the summer, it is hard to breathe in heavy traffic.

Forget about power windows, power steering, antilock brakes, air bags, air conditioning, on-board computers, sunroofs, convertible tops. They are not part of Russian cars. Automobiles are just vehicles, a means of transportation. But a car is still the ultimate possession for a Russian.

Russian factories produce three types of cars for the public. The Moskvich is made in Moscow by the Lenin Communist Youth Factory (it is still called that). The quality of this car is described in a joke: What do the Moskvich and a pregnant teenager have in common? Answer—both are an embarrassment to the family.

One has to be really handy to keep this car going. Spare parts are in short supply and very expensive. In fact, every Russian who owns a car must have a good knowledge of automobile mechanics. That is why so many Russian immigrants work in body shops in the United States.

In 1968, the Soviet Union bought a factory from the Italian automobile giant Fiat and placed it in a new town on the Volga River. The 1968 Fiat was renamed *Lada* and became the major mode of transportation in the country. There is a story that Prime Minister Aleksey Kosygin once visited the Lada factory and fell in love with the car. He immediately called the management together and told them: "All of you will be fired on the spot if you try to improve any part of this car." Legend or truth, the Lada has not changed much since.

The advantage to the Lada is that many parts for it are manufactured in Europe, so it is fairly reliable. And even though the design is old, it is still Italian. The Lada is even exported to some European and Middle Eastern countries. Special firms remodel it according to Western standards and then sell it. The Lada is probably the cheapest car in its class in the world, so there is a ready market for it.

The third Russian brand is Volga, made by a huge military factory in the city of Nizhny Novgorod (formerly Gorky) on the Volga River. This is a bigger car and is the favorite of top bureaucrats. It is also used as a taxi. The Volga was for many years the symbol of prosperity and prestige in Soviet society.

Not anymore. Now one can see many foreign cars braving the potholed Moscow streets. Newly rich Russians prefer Mercedes, Volvo, BMW, or Lincoln models. The rest of the population is catching on that a Western clunker is better than a brand-new Russian car. In the last few years, Russia has become one of the major used-car markets in Europe.

Old people in Russia will never learn WordPerfect, use an electric blanket, make bread in a bread-making machine, or leave a message on an answering machine. But new generations are learning. I watched a six-year-old boy teach his dad how to play Super Mario Brothers-2 on a Game Boy.

His father was trying hard. PS

Siberia at the Crossroads

[Continued from page 40]

Union's center for growing cotton, a notoriously thirsty crop. Today, the sea is only a third of its former size. There are no more fish. Trawlers lie rotting miles from the sea.

This was no accident. A former president of the Academy of Sciences of Turkmenistan, quoted by Soviet authors, said: "I belong to those scientists who consider that drying up the Aral Sea is far more advantageous than preserving it." He assumed that a crust would form on the dry seabed, which could then be farmed. But he was wrong.

Instead, the fierce Central Asian winds whip up a deadly harvest of salt and pesticide residues from the dry seabed—an estimated 75 million metric tons of it a year—that destroys soils, blankets vegetation, and, it is increasingly clear, kills many inhabitants of the newly independent republics of Kazakhstan and Uzbekistan. There are epidemics of anemia and throat cancer. Infant mortality is soaring.

"Commissar Cotton" has created a human and ecological catastrophe here with few parallels anywhere in the world. In 1990, the director of the Soviet Institute of Geography in Moscow predicted that the crisis was "so serious that...only a short time remains before life and work in the region become impossible."

Plans to divert Siberian rivers south to replenish the Aral Sea have been proposed and dropped many times by Soviet scientists. Earlier this year, the nations of the Aral region signed an accord aimed at preventing the sea from shrinking further. The United Nations has drawn up a scheme for saving water on farms. But it will cost money.

And that is the story for many of Russia's environmental problems, says Zabelin. "We had an illusion that conversion [to a cleaner environment] didn't mean big money—that once the communists were gone, it would all be better. But it does require big money, not just in cleanup technologies, but in replacing old production equipment."

Zabelin left the Yeltsin administration last September to return to full-time work for the Socio-Ecological Union, which now has 150 local branches. "All activity in the administration today is led by peoples' selfish interests. It is useless to stay. It is more important to develop a grass-roots movement," he says.

He fears that a humbled nation, with its naive hopes for the fruits of democracy dashed, will turn to extremes. "Some people want order and protection, to restore their motherland," he says. That could bring to power the neofascist leader Vladimir Zhirinovsky. Though Zhirinovsky has no published policies on the environment, his supporters already have control of the two parliamentary committees concerned with the environment and natural resources, says Zabelin. The environment committee is chaired by Mikhail Lemeshev, a Russian environmentalist who in 1991 published *Bureaucrats in Power: Ecological Collapse*, a detailed examination of the inefficiencies of Soviet centralized decision-making.

Zabelin, a political opponent of Lemeshev, nonetheless says that Lemeshev "will push the green idea." But just as likely as an elected right-wing government is a military coup, Zabelin predicts. "I'm afraid we will have a military regime in the near future," he says. "Maybe that would be better for the environment than the chaos now."

Stalin's "iron brotherhood" may be gone. An enfeebled state may no longer be able to dress Siberia in cement armor. But the environmental future of the largest country still looks grim. PS

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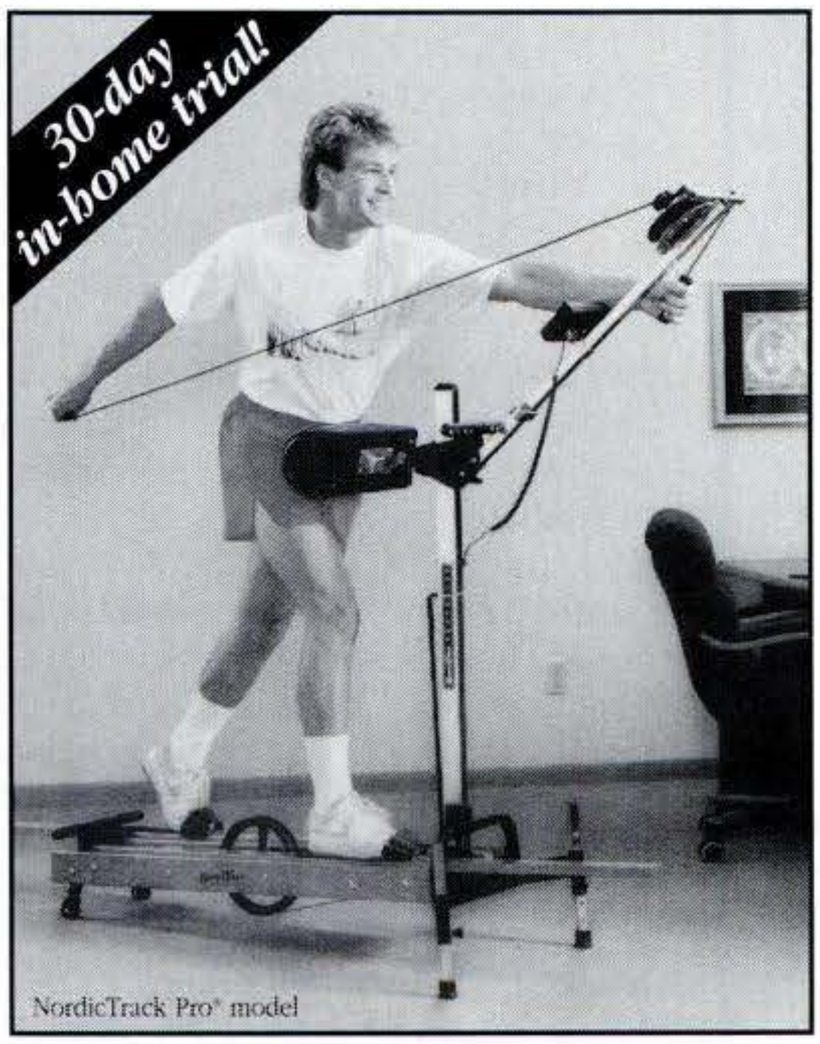

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How the Soviets Got the Bomb

[Continued from page 31]

is today called "the physics of safety.")

Kurchatov and Khariton worked powerfully in tandem. They were not simply scientific leaders, but also physical protectors of their subordinates, with the ability to intervene and negotiate even with Beria. This protection was very important in the post-war atmosphere of growing repression and ideological pogroms against intellectuals during what was known as the "struggle against cosmopolitanism" —that is, Western bourgeois influences.

Until the first Soviet test explosion in 1949, Beria kept a shadow group of scientists and engineers ready with a contingency plan behind the scenes, just in case the first team failed. The second group's very presence constituted a kind of sword of Damocles poised over the heads of the Kurchatov-Khariton team. The 1949 test was thus awaited with a mixture of hope and desperation by both groups. The Soviet fission nuclear bomb, called Joe 1, exploded successfully in August 1949 at the Semipalatinsk test site, about 1,800 miles southeast of Moscow and about 300 miles from the Mongolian border, in what is now independent Kazakhstan.

For this Arzamas-designed Soviet fission bomb, the Russians followed the guidelines of the original American plutonium bomb as closely as they could on the basis of intelligence reports. Called Fat Man, that bomb was dropped on Nagasaki, Japan, on August 9, 1945, with a yield of 22,000 tons of TNT. It used a plutonium core surrounded by explosives that imploded, compressing the core and creating a fission reaction.

This first Soviet bomb was thus essentially an imitation design, based on pilfered documents gained via espionage. Nevertheless, tremendous effort was required from leading scientists (and from industry) to bring it to fruition in a successful device. This dual origin of the Soviet bomb has fueled a violent controversy between the scientific and intelligence communities over their relative contributions to the nuclear program.

There is no doubt that the intelligence community played a major role in the Soviet bomb program, much of which is now coming to light. The Russians recently opened part of their files on early nuclear espionage activities in the United States. The KGB, which had been deeply involved in efforts to steal American secrets, felt that in the aftermath of the Cold War its contribution had not been appreciated enough.

Recent interviews given by a number of former intelligence officers such as Col. Anatoly Iatskov, the former chief Soviet spy in New York in the 1940s, revealed that frustration. For example, Iatskov complained that for his priceless service to the fatherland—delivering a sketch of the American bomb—he had been awarded only the "Combat Red Banner Order," a prize much lower in esteem than those granted the leading Soviet nuclear physicists, Kurchatov, Khariton, and Yakov Zeldovich. *They* were given the state's highest honor, "Hero of Socialist Labor"—three times.

Yuly Khariton recalls one episode in the science/KGB debate: a meeting with Stalin, when the dictator had to decide whether to copy the American design based on plutonium, or to pursue the Soviet original design for a uranium bomb. In a state of nuclear paranoia, Stalin opted to press the scientists to copy the American bomb and hurry up with the first test "before the Americans blast us." This episode reflected the mistrust of their own scientists by the Soviet government.

The most important intelligence contribution to the Soviet nuclear bomb program was made by a single atomic spy (see "Were They Spies?"). In the summer of 1950, British security agents arrested Klaus Fuchs, a German refugee from Nazi Germany who had fled to England. Fuchs had arrived at Los Alamos in 1944 as a member of a British nuclear team working on the Manhattan Project.

The KGB has now publicly acknowledged that Fuchs was a valuable mole, who passed documents on the American plutonium bomb to the Soviets. In 1993, the official Russian TV program Channel 1 broadcast: "Klaus Fuchs, a talented physicist who had emigrated from fascist Germany, handed over extremely valuable information to Soviet intelligence. Thanks to him, our country was able to speed up its own program by at least two years."

While the Soviet nuclear weapons establishment started as the pupil of the Manhattan Project, it quickly accumulated its own momentum. By the late 40s, Soviet bomb makers were already moving toward genuine Russian designs. Then in the 50s, the basic concepts for the present generation of hydrogen bombs were developed and tested. Nuclear historians sometimes attribute the origin of the Soviet H-bomb design to American ideas. Here, too, former KGB spymasters claim an important role for themselves. However, Andrei Sakharov's memoirs and the recent arguments of Yuly Khariton provide a strong case for the originality of the Soviet design.

Sakharov, who joined the Arzamas team in 1949, discovered that the early Soviet work on the hydrogen, or fusion, bomb was based on a flawed concept. He related its origin to an early American version, stolen by the KGB and later dismissed as unusable. Most probably the KGB had obtained plans for the so-called "Super," a preliminary design unsuccessfully pursued at Los Alamos before Edward Teller and Stanislas Ulam conceived a brilliant alternative in 1951. Sakharov describes the massive but futile efforts of the Arzamas team to pursue this unworkable early American approach before he was able to come up with a real breakthrough—a completely different idea.

Khariton's account of the H-bomb categorically rejects the claim of the retired spies: "In the final analysis, the eventual prototype of the H-bomb, on which all modern nuclear weapons are based, stemmed from our own work— the Americans were first to test this weapon in 1954, and we tested our own in 1955. But we worked completely independently." On the basis of fragmentary recollections of several leading Soviet physicists, one could reconstruct a complete chronology of events, leading to the H-bomb test in the autumn of 1955.

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taly Ginsburg, an eminent Soviet physicist. He proposed the use of lithium deuteride (deuterium is a heavy isotope of hydrogen). The explosion of a fission "trigger" would bombard the deuteride with neutrons, producing the still heavier hydrogen isotope tritium. And a deuterium-tritium fusion is the most powerful of thermonuclear reactions. Ginsburg's suggestion, made in 1949, Sakharov called "the first idea."

The second idea was proposed by Sakharov himself in the same year: The fission of a very heavy isotope with many electrons per atom, such as uranium-238, surrounding the light thermonuclear fuel (with far fewer electrons per atom), would produce an enormous compression, greatly enhancing the rate of fusion reactions. This process was nicknamed "Sakharization," after its originator. This word in Russian literally means "sugaring"—*Sakhar* means sugar. Neutrons emitted in the fusion reaction would, in their turn, enhance fission by bombarding the uranium-238. The overall sequence is the fission-fusion-fission cycle.

These concepts were not suggested by American scientists until Teller and Ulam proposed similar steps in 1951. The Americans then almost immediately made a final breakthrough by harnessing the tremendous radiation effect of thermal X rays. This was the equivalent of Sakharov's third idea (proposed by him jointly with Zeldovich in 1954). However, the Soviet discovery was made independently; the Soviet atomic intelligence network had ceased to exist long before, as the spymasters themselves have admitted.

Indeed, KGB Col. Iatskov admits that all the American leakers abruptly stopped cooperating with the Soviets after August 1949. Apparently, they considered the successful test of the Soviet atomic bomb that August as the complete fulfillment of their "moral" duty to help restore nuclear parity. But Iatskov insists that he had enough time to pass the secret of the future H-bomb to the Kremlin in 1948.

So what is the answer to the science/espionage debate? There is no question that even without the assistance rendered by the KGB, the Russian scientific establishment would have developed the atomic bomb independently (as they did with the hydrogen bomb), only some two years later. Perhaps the last word should remain with the late Andrei Sakharov, physicist and dissident, who was always skeptical about the importance of spies. He once told a meeting at my institute: "There was only one secret—that it is possible to make a nuclear bomb." PS

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Nuclear Chaos

[*Continued from page 59*]

arms, and return all of its nuclear weapons.

Although the theft or capture of nuclear devices by terrorist groups or commandos working for other nations is possible, the most likely "loose nuke" scenario (as it is called by proliferation experts) involves the clandestine sale of either bomb-grade fissile material or an actual warhead.

Two factors, both stemming from mounting political anarchy, make such sales increasingly likely. First is the simultaneous growth of the get-rich-quick criminal class and the miserably paid nuclear custodians: scientists, engineers, technocrats, and personnel who are supposed to guard fissile material and warheads. The greed merchants—many of them real-life (though murderous) Damon Runyan characters, complete with BMWs, bimbos, and bodyguards—have dizzying amounts of money to pay laboratory workers, key bureaucrats, and guards who live in squalor and who try to make ends meet on perhaps $12 a month.

Second, the former USSR's once tightly sealed borders are now so porous that a thriving black market has taken root from Eastern Europe to Vladivostok, where everything from electronics to stolen cars moves with near-freedom. What border guard at a lonely checkpoint would confiscate a small heavily insulated crate weighing perhaps 100 pounds or even 10 times that much instead of taking $250—four year's pay—and allowing it to pass?

Buying a finished weapon, or several of them, is the easiest way to gain entry to the nuclear club. And as events in eastern Germany in 1991 showed, such a scenario is not farfetched.

That year, a 28-year-old senior lieutenant in the Special Troops of the Soviet General Staff—the group assigned to guard nuclear weapons—arranged to steal a 1,500-pound, city-busting Scud nuclear warhead from a bunker at Alten-Grabow in eastern Germany and smuggle it by truck and barge to members of Greenpeace in West Berlin. There, the activist environmental organization planned to unveil it at a news conference, proving that nukes could be acquired by outsiders, whatever the Kremlin claimed. Greenpeace planned to end the event by publicly asking the weapon's embarrassed owner where it wanted it returned. Just before the theft was to take place, however, the lieutenant's unit was abruptly withdrawn to Russia, taking its warheads with it.

In an appearance before the Senate Government Affairs Committee in May, Mikhail Yegorov of the Russian Ministry of Internal Affairs said that organized crime groups were trying to penetrate the facilities of the defense establishment and steal nuclear material. And FBI Director Louis Freeh told the Committee: "We are gravely concerned Russian organized crime members may have already attained...the capacity to steal nuclear weapons." To help Russia deal with such problems, the FBI is establishing an office in Moscow.

While losing one or more nuclear devices to terrorists would be dangerous enough, it would pale in comparison with a Dr. Strangelovian doomsday system that was set up during the height of the Cold War to ensure that the United States would not survive even if it launched a "decapitating" strike against the Soviet political leadership and the general staff. The computerized system, which is still in place, is called "dead hand" because it was designed to be switched on at the start of a crisis, and to order all-out nuclear retaliation even if the whole hierarchy of Soviet leadership perished.

The dead hand system marks the first known instance in the nuclear era in which a machine has been invested with the ability to destroy most or all of an entire country. Although the system was designed to respond to an attack, experts agree that it is particularly dangerous because Russia's faulty early warning system, the capture of command posts in a civil war, or even a computer glitch could turn it into a first-strike system.

The system's components are said to be buried as deep as 900 feet beneath the Lenin Library, and at other sites south of Moscow. If the dead hand system's ground-level sensors picked up nuclear explosions, and if communication links with the national command authority were broken, low-frequency signals would go out to launch special rockets.

The rockets would fly high over missile fields and other military facilities, broadcasting launch orders to ballistic missiles and bomber bases whose targets are pre-selected. The communications rockets were designed to fire missiles from submarines at sea too, but hardly any subs patrol nowadays for lack of fuel and lack of a mission. Although both sides' ICBMs were targeted on the oceans instead of strategic areas this spring, they could quickly be retargeted. And even a massive nuclear attack on the sea would create an unimaginable ecological catastrophe.

The Cold War may be over. But the nuclear danger it spawned has a half-life that will extend well into the foreseeable future. PS

From Russia with Mud

[Continued from page 47]

ward and skirts a creek. After the first 90-degree turn, I realize there is no power steering. After the first sharp downhill, I realize there are no power brakes. With leaf springs front and rear and solid axles, every bump and lump is telegraphed directly into the cockpit. The seats do little to cushion the blows.

The Russians have taken simplicity to new heights. The last thing you need if you're chasing a tank through a bog or over fallen trees is power-assist units that burn out, or complex suspensions and axles that go awry. So none of the luxuries that earmark Western sport utilities are found on this beast.

Manhandling the UAZ on several laps around a course featuring boulders, felled trees, and steep hills, I break into an all-out sweat. With a wheelbase measuring a mere 94 inches, the UAZ effortlessly pirouettes around trees and boulders, an amazing feat considering its 3,505-pound curb weight. Almost nine inches of clearance at the rear differential makes overrunning obstacles a breeze. Although I didn't get a chance to try it, UAZ claims a 27.6 inch-deep river-fording capability. Engine torque is 127 pound-feet at 2,100 rpm, and the choice of eight different gear settings wrings the most from the motor.

All of this lends an honest, old-fashioned feeling to the UAZ. And that's part of the charm that has Reston, Virginia-based UAZ of America betting that the vehicle will be a hit. A U.S. version will make several concessions to luxury-minded Americans: power steering, a radio, a new dash, and more comfortable seats. Still problematic is the powerplant; UAZ of America would like to use a GM V6 in place of the Russian engine that will not pass U.S. emissions standards. Other alternatives include a Volkswagen V6 or an unspecified Mazda engine.

Beyond the engine glitch, there are a host of U.S. requirements the vehicle must meet before it can be sold here. Sharp welds need to be smoothed, side running lights must be installed, and the seven-ply Russian tires—designed to withstand bullets—need to be replaced with U.S.-rated rubber. The UAZ could clear the engine and safety hurdles and may be offered for sale about a year from now.

It's a long shot that the UAZ will displace the Jeep or the Land Rover. Sport utilities spend most of their time on the highway, hardly the natural element for a battlefield vehicle. But for born-and-bred toughness and a retail price expected to be about $13,500, this new badge might be novel enough to give the big guys a real run in the mud. PS

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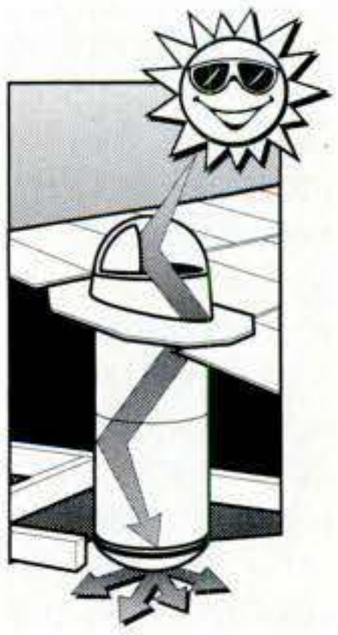

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Moscow rules

[Continued from page 27]

ship. Sagalevich piloted five of the 17 dives made by the *Mir I* and *Mir II*, Finnish-built manned submersibles capable of diving to 6,000 meters.

"Basically, we work only on a contractual basis with different groups around the world," Sagalevich told me. "There's no other way. My institute, the Russian Academy of Sciences, the government—they have no money to support our research." Today Sagalevich and his colleague, chief scientist Lev Moskalev, work with countries ranging from Germany to Mexico. One of their most important jobs, undertaken with support from several governments, is monitoring the state of the Russian nuclear submarine *Komsomolets*, which sank in the Norwegian Sea in 1989. Lying just 300 miles off the Norwegian coast, it gives nearby countries grave concern over the possibility of leakage of radioactive material.

Even the prestige of the Nobel Prize does not confer immunity from loss of funding and the need to seek international ventures. Academician Aleksander Prokhorov is director of one of the most respected of all Russian scientific institutes, the General Physics Institute in Moscow. In 1964, he shared the Nobel Prize for physics with a fellow Russian, Nikolai Basov, and with Charles H. Townes of the United States for the elucidation of laser and maser theory. Today, Prokhorov's Institute, like all the others, is suffering.

"Even though we are dedicated to basic research," the lanky, white-haired scientist told me, "the drop in military orders affects us greatly. The military establishment understands that it needs to support fundamental research because new ideas, new scientific principles, are very important for developing new weapons. For example, some of the laser research at my institute is weapons-related. But now the military ministries don't have money, so they can't go on funding us. About 30 percent of our budget came from the military; the rest came from the Academy of Sciences.

"Now we don't have enough money for salaries, and scientists have low salaries compared to other people anyway, especially to people who buy and sell. We have practically no money to buy materials, replacement components, new equipment. The government says that just now they don't have more money to support science, but later, when they have more money, they'll give more to science. By that time science in Russia might be dead. And everyone knows that if somebody dies, you can't bring him back to life."

So now, Prokhorov says, he is obliged to do research with other countries, including the United States, Germany, and Japan.

One of the most potentially fruitful areas of this research is cancer therapy. "You might think this is strange," says Prokhorov, "because we are a physics institute, not a medical institute. But we have developed solid-state fiber-optic lasers that can be used to treat cancers lying deep within the body, like stomach cancer." Pinpoint, intense laser light of the right wavelength, from one to ten microns, is passed through a fiber-optic endoscope to the site of the cancer. The lasers are also being used to treat skin cancers.

Prokhorov particularly regrets the cancellation of an ambitious space laser project because of lack of money. His institute developed a LIDAR—a kind of laser ranging device—that he wanted to install on the Russian space station *Mir*. "We would have been able to evaluate the state of the atmosphere—the presence of aerosols, the condition of the ozone layer," Prokhorov said wistfully. "But the government had no money to pay for this project.

"Besides, we are less concerned than the West about the ozone hole and global warming, at least for the time being...maybe later. For now we have other, more immediate problems. Because we have so much pollution of different kinds, we have many health problems. So, for the present time, we are more concerned with local ecological problems than global ones."

Another institute's collaboration involves the U.S. government directly. In 1992, the U.S. Department of Energy agreed to fund experiments on the T-10 tokamak at Moscow's Kurchatov Institute of Atomic Energy. The tokamak is a doughnut-shaped type of fusion reactor, which creates a magnetic field to confine the plasma of fusion fuel. The work was to supplement fusion-energy research being conducted at General Atomics of San Diego, Calif. The salaries of 116 Russian scientists for one year totaled $90,000, or about $65 a month for each researcher. That was some seven times the Russian average wage at the time, but a ridiculous and insulting pittance by American standards.

The head of the division of Kurchatov that was involved, which now is called the Institute for Fusion Research, is Boris Kadomstev, whom I first encountered on a visit to the tokamak facility in 1978. When I visited him in June 1992, shortly after the DOE contract had been signed, he was extremely resentful over what he considered a virtual rape of Russian science. When I met him again in April, I reminded him of his reaction and asked whether he felt any different about the deal, which had been renewed after the original contract expired.

"Not really," Kadomstev answered. "My original complaint was that there was very little money for a very big job, and that hasn't changed. The size of the contract is still about $100,000, and it's to operate the T-10 only for specific experiments for General Atomics. It actually takes about three or four times that much to perform all our work on the T-10. The rest has to come from the government, part from the Ministry of Science, which pays for our salaries, and part from the Ministry of Atomic Energy, which pays for materials, equipment, and miscellaneous support."

Kadomstev's institute has also built a larger tokamak, the T-15. But experiments on this machine have virtually ceased. The T-15 is far more complex than the T-10, and because it uses superconducting coils to maintain the magnetic field, it needs to be cooled by liquid helium, which must be constantly replenished. That makes it far too expensive to run.

"To operate both the T-10 and the T-15 tokamaks in the right way," says Kadomstev, would not take much money, about three to four million dollars per year. But the Russian science budget now is very small. As a percent of the gross national product, it's one-third as much as it was in 1990, and that product has also shrunk. So the budget for science is really tiny.

"This is especially severe for big science, big installations like mine. Plasma fusion research demands big machines, and it is very difficult to continue operating them now. And there is no indication that the situation will improve in the future. Nevertheless, physicists and other parts of the scientific community continue to struggle to work. It is our tradition, and our life."

Beyond such international cooperative arrangements, straight-out gifts to the cash-starved Russia also have a role. To prevent Russian science from "slipping into a black hole," the international financier and billionaire George Soros announced in December 1992 that he would establish a "Noah's Ark"—a private foundation, the International Science Foundation, to contribute $100 million of his own money to support basic science in the former Soviet Union. His foundation would consider applications for grants directly from individual scientists, sidestepping the encrusted system of institute and Russian Academy approvals that previously throttled the flow of money.

One of Minister Saltykov's plaints has been that, under the old regime,

there was no real system of peer review of grant applications comparable to that in the United States. Instead, funds were often shunted to those distinguished by political heft and Communist Party loyalty. Commenting on the Soros plan, Saltykov said: "The new approach will select only the most creative people. It will undoubtedly lead to a shift in power away from the apparatchiks to the scientists themselves."

The original $100 million sum was followed by the promise of an additional $12.5 million from Soros this March, provided that the Russian government would contribute matching funds. So far, about 20 percent of the 9,000 grant applications received have been approved, with the size of the grants ranging from $10,000 to $50,000. Unfortunately for the Russians, the money is due to run out in the summer of 1995.

Not every scientist in Russia is happy about the Soros grants. Evgenii Dianov, of Moscow's General Physics Institute, is skeptical about their motivation and eventual impact. Dianov heads a research group of about 100 scientists who work on both fundamental and applied science problems in the field of fiber optics.

"At first sight," Dianov told me, "the Soros grants looked all right—the United States is just trying to help us, help Russian science. But after thinking about this very deeply, it seems that it is not really help, but good business for the United States, and taking advantage of the present very poor situation of Russian scientists.

"How does it work? Poor Russians with no money to pursue their scientific interests are asked to apply for grants by submitting their best ideas—as many as possible—to the United States. Some of the grants will be supported, but most will be rejected, because there is not enough money. So scientists in the United States—in universities, in research laboratories—get many valuable fresh ideas in physics, chemistry, mathematics...we don't have stupid people in Russia. And of course, the United States can benefit from many of these ideas they get at no cost."

When asked whether his laboratory had applied for Soros grants, Dianov replied that he had submitted proposals for three or four projects, and that one was accepted.

Minister Saltykov dismisses such thinking as, essentially, sour grapes. "Don't American scientists also get disappointed if their grants get turned down by the U.S. National Science Foundation?"

Dianov's view of America may be jaundiced by previous experience. His was one of the first groups to contract with a major U.S. corporation in a cooperative venture. In May 1992, the fiber-optics group signed a one-year contract with AT&T Bell Labs to perform sophisticated research in such areas as high-strength fibers and laser-fiber interactions. AT&T sought out his group, Dianov said, because the scientists at the General Physics Institute have the reputation of probing physical phenomena very deeply, as opposed to the approach of American facilities like Bell Laboratories, whose researchers Dianov characterized as "attempting to understand something just deeply enough to be able to produce a commercial device. It's very prestigious to invent a significant new device, and it's good for technological progress. But in fundamental science, the real prestige comes from deep understanding of the underlying phenomenon."

When I interviewed Dianov in June 1992, just after this arrangement had been signed, he was less than happy with the financial arrangements, which gave each member of the group less than $100 a month. His new arrangement is better, he said now, not because the AT&T funding has been substantially increased, but because the money is now shared by only ten or so researchers, so individuals are better off.

"On the other hand," Dianov told me, "cooperation with AT&T has been very good advertising for my team. So now I have contracts with other companies, some in America, such as DuPont, and some in Canada."

It is a reflection of the state of science in Russia that less than half of Dianov's funding comes from the State's budget for his institute; the rest comes from his foreign contracts.

"It seems," he said bitterly, "that the whole budget for academic science equals two MiG-29s. One result is that my team has lost 11 persons to other countries, the most ambitious and talented, some in very high supervisory positions, very bad for our state."

Nevertheless, Dianov says, he is optimistic about the future of Russia and Russian science.

"You see, the greatest potential of Russia is in its richest resource—the Russian people. Gradually, we'll find a way to restore our country, and our science." PS

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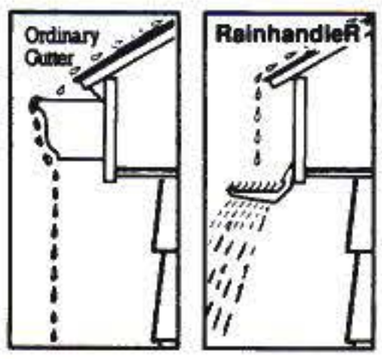

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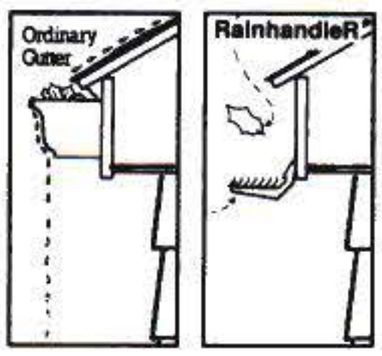

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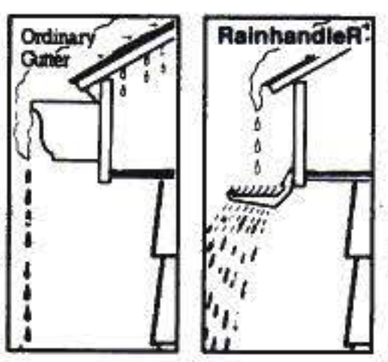

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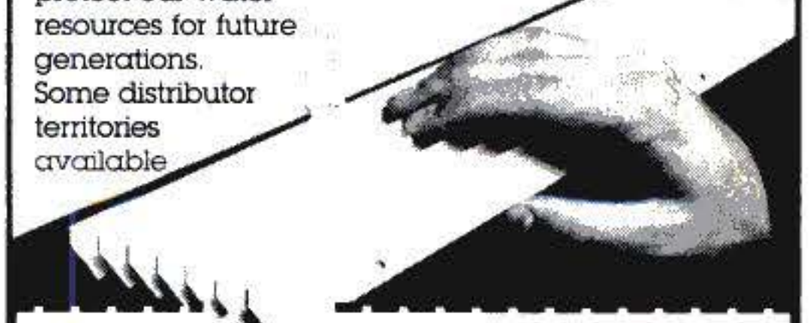

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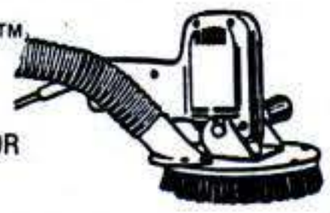

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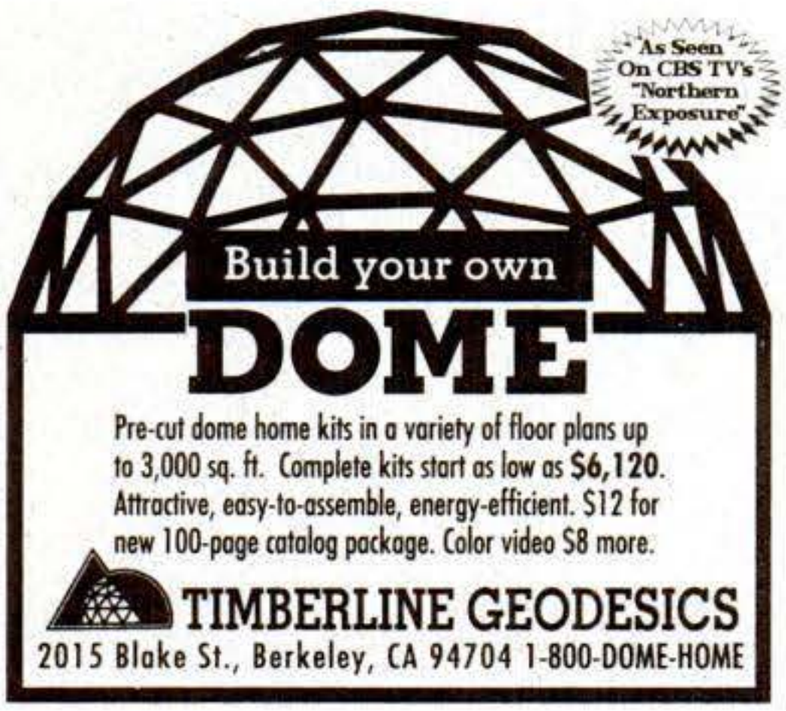

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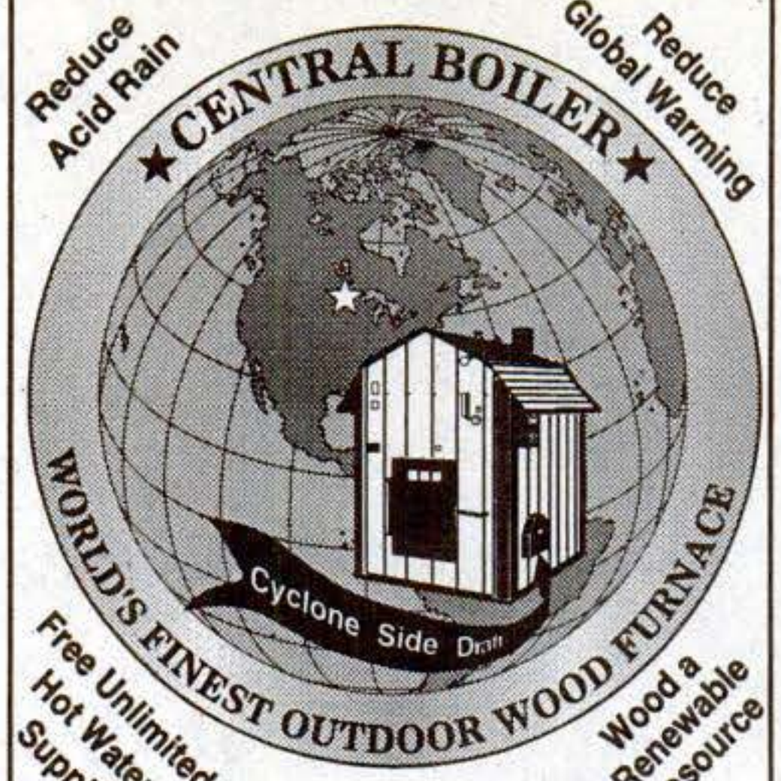

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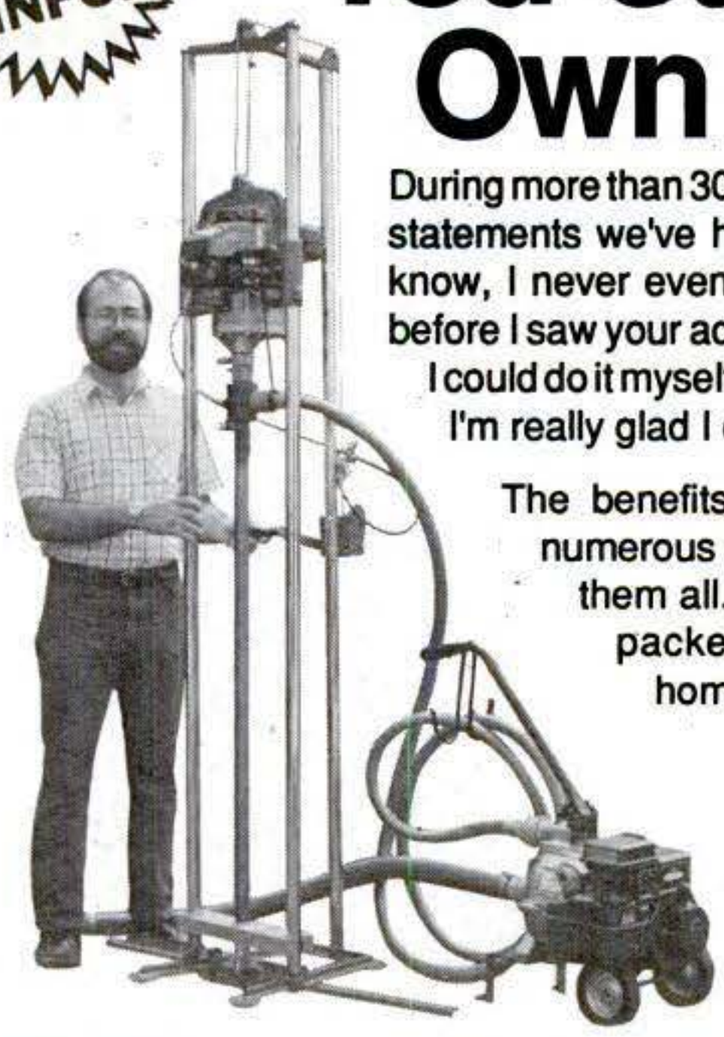

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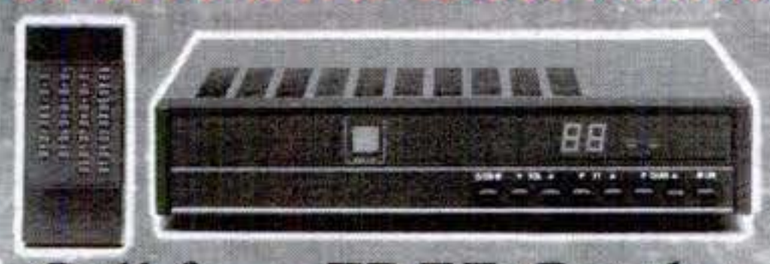

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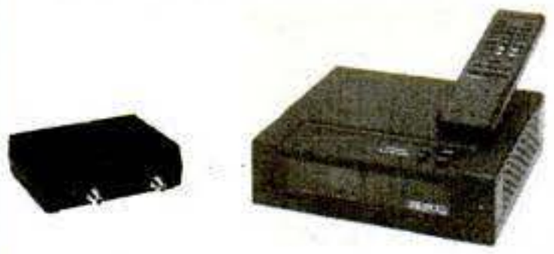

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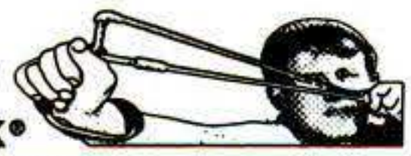

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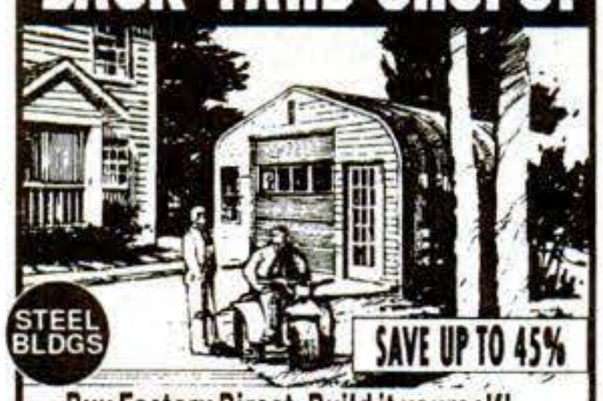

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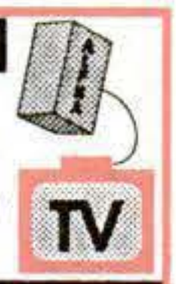

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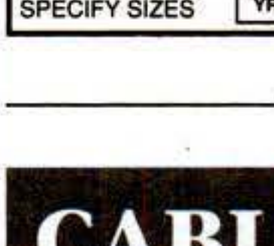

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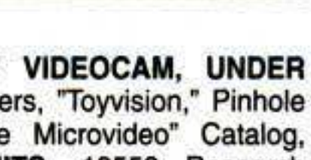

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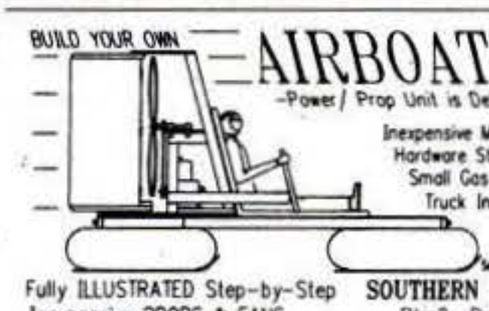

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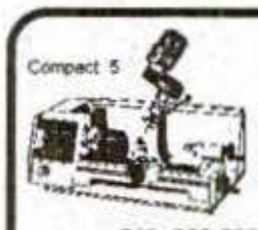

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75 Years Ago

Early Chain Saw

A mechanical saw can be operated by one man and can cut as much cordwood in a given time as ten men using handsaws. The saw costs less than three cents a cord for fuel and upkeep. A chain and sprocket connected to a four-horsepower gasoline engine oscillate the saw by means of a crank arm mounted on a shaft. The machine can be carried by two men. —*August 1919*

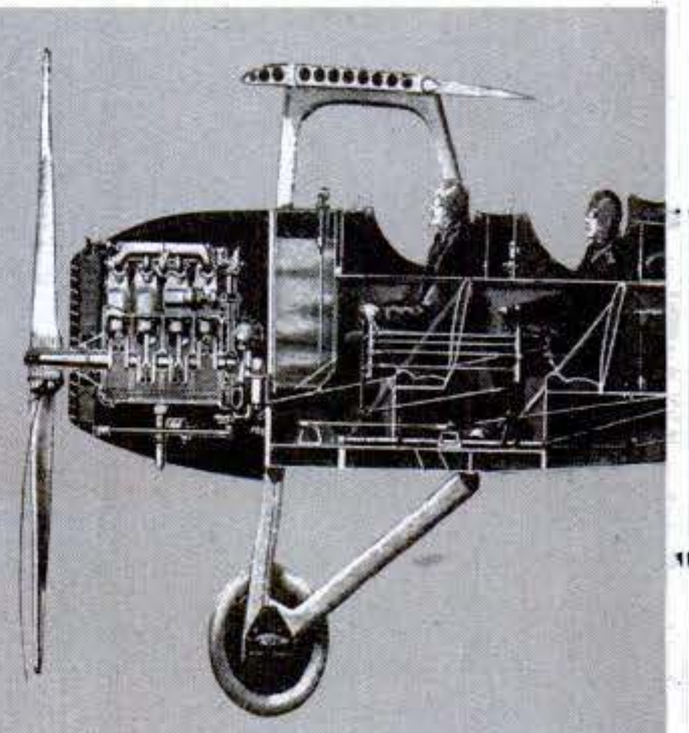
The first hand-held chain saw was invented in 1926 by Andreas Stihl. The company Stihl founded represents the largest selling brand of chain saws worldwide today.

75 Years Ago

Faster Planes

When airships are closely compared to steamships, it becomes evident that mechanical efficiency is more essential for speed in the air than on the water. One obstacle to speed is the bulky landing gear on planes. Wheels that fold up into the hull during flight would eliminate this air drag. Open cockpits and struts between biplane wings add additional wind resistance that slows the flight of the plane.—*August 1919*

In the mid-1920s, Sherman Mills Fairchild built the first American plane with retractable landing gear and an enclosed cockpit.



50 Years Ago

B-29

The Army Air Force cagily reported that the B-29 Superfortress has a "very long range" and a ceiling "well over 30,000 feet." It did reveal that the wingspan is 141 feet, the nose gear weighs 1,036 pounds, and it has four 2,200-hp engines. —*August 1944*

During World War II, 4,000 B-29 Superfortresses were built. They could fly 5,333 miles with a full bomb load at 400 mph. The B-29 Enola Gay *dropped the atomic bomb on Hiroshima, Japan, in August 1945.*

25 Years Ago

Virtual Traffic Signs

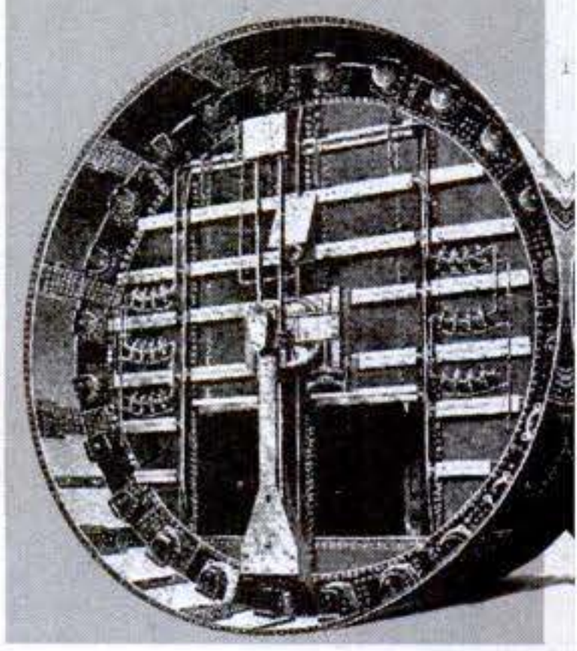
A new tele-optic device called Holosign can project images into thin air. Highway signs could be placed by remote projectors directly in a driver's line of vision, as he approaches an exit. Once the car passes beneath the sign, it disappears from the driver's view. Projectors can be placed in out-of-the-way spots, so cars that run off the road won't damage them. Holosigns are glareless and can be seen clearly through rain or snow. —*August 1969*

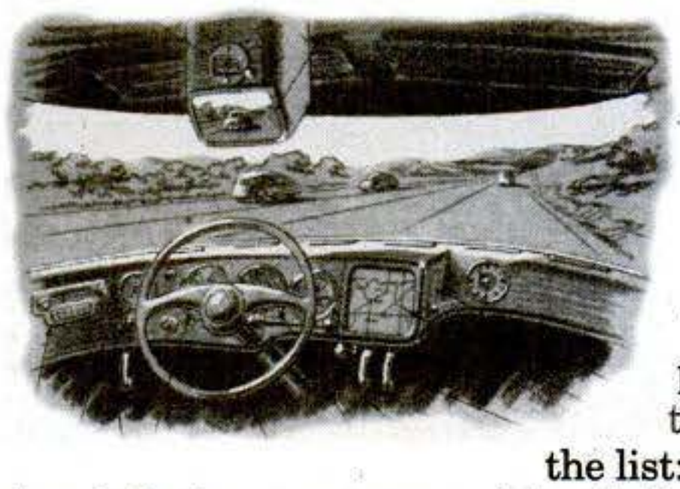
100 Years Ago

Tunneling Technology

The 6,036-foot-long St. Clair tunnel runs from Sarnia, Ontario, to Port Huron, Michigan, beneath the St. Clair River. The 20-foot-diameter tunnel was dug using a shield, a cylinder of iron twenty-one feet and six inches in diameter with a sharp cutting edge. This edge was driven into the bed of clay, which was then excavated from within the shield. Three shifts of men working round the clock moved two shields, one from each side, toward the center. —*August 1894*

The St. Clair tunnel is still used for freight and passenger trains. A 29-foot-diameter tunnel under construction next to the St. Clair will allow the passage of double-stacked containers on rail cars. It's scheduled to open in March 1995.





50 Years Ago

Post-War Cars

POPULAR SCIENCE asked readers what they would like to see in post-war cars. Safety features were at the top of the list: "I want to see the road ahead. Let's cut out some of that ballooned hood and its glaring reflections. The feature most needed is driver-in-front design. I'd have an escape hatch in the rear, and opaque shutters to control glare from above." Other suggestions included flashing lights on the instrument panel to signal emergencies such as low oil pressure, dangerously high engine temperatures, and a nearly empty gas tank.—*August 1944*

100 Years Ago

Garbage Power

A refuse-burning plant has been set up in Halifax, England, to supply electricity to the town. A special flue construction in the furnace enables it to draw four times as much steam per pound of garbage as any previous experimental power generator fueled by trash. —*August 1894*

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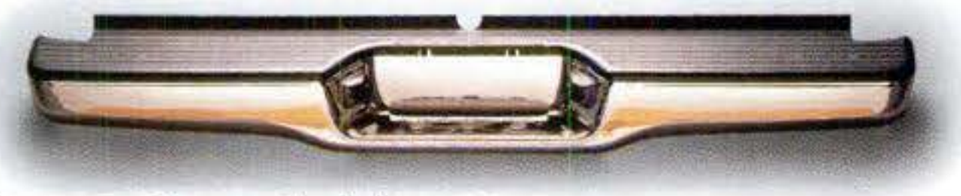

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